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Fig. 1. The shelf ice on the north coast of Ellesmere Island, with Disraeli Bay upper right, and Ward Hunt Island at its mouth, 16 July 1950.

ARCTIC ICE ISLANDS

L. S. Koenig, K. R. Greenaway, Moira Dunbar, and G. Hattersley-Smith

Introduction

At the First Alaskan Science Conference, held in Washington, D.C. in November 1950, the work of the U.S.A.F. in discovering and following the movement of exceptionally large masses of ice in the Arctic Ocean was first made public. The largest of these masses is some 300 square miles[1] in area, and because of their size and stability they were first referred to as "floating islands" and later as "ice islands".

From the air ice islands are readily distinguished from the pack ice by their homogeneous appearance and strikingly regular surface pattern. Their surface looks ridged or rolling, with wide intervening troughs. The ridges, or rolls, are as much as half a mile and more from crest to crest, and are roughly parallel, running from one edge of the island to the other. There is often some indication of a drainage system with small streams cutting across the large troughs. Most striking of all is the ability of the islands to keep their shape over a period of years, which suggests great thickness and hardness. Ordinary pack ice, by contrast, breaks and reforms continually under the influence of pressure, and although particularly heavy floes may remain substantially unchanged for several years they cannot be distinguished from the surrounding floes which they closely resemble.

The ice islands can be divided into two groups: a few large islands which are drifting in the Arctic Ocean and a number of smaller islands which have found their way into the channels of the Canadian Archipelago. They almost certainly originated on the north coast of Ellesmere Island, where there is a fringe of ice showing the same unusual surface pattern.

Since 1946 members of the U.S.A.F. have been following the drift of three large islands in the Arctic Ocean, and on 19 March 1952 a landing was made on T3, the smallest of these, which was then two degrees from the north pole.[2] We hope to publish a detailed report on the surface observations when these are available. The following accounts deal with the discovery of the two groups of islands, references to possible ice islands in the accounts of earlier travellers, and some speculative comments on their origin.

[1]Throughout these papers on ice islands measurements are given in nautical miles.

[2]At this time another ice island, which was at first mistaken for T3, was discovered some 40 miles to the west of T3.

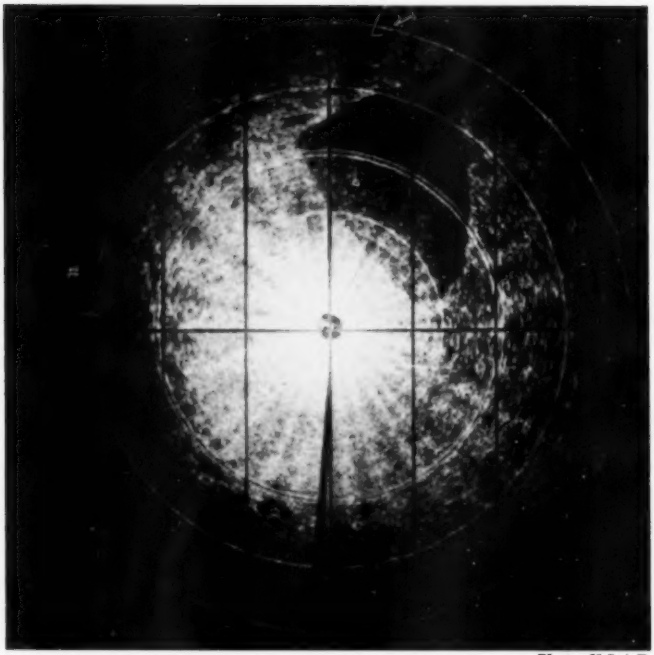

Photo: U.S.A.F.

Fig. 2. Recent radar photograph of T1, January 1952.

PART I. DISCOVERY OF ICE ISLANDS ON U.S.A.F. FLIGHTS OVER THE ARCTIC OCEAN. *By Major L. S. Koenig, U.S.A.F.*[1]

On 14 August 1946 an enormous mass of floating ice, considerably thicker than the pack ice and more than 200 square miles in area, was discovered less than 300 miles north of Point Barrow by an aircrew of the 46th Strategic Reconnaissance Squadron (Photo) stationed at Ladd Field, Fairbanks, Alaska. This original sighting was by radar and the ice mass was designated Target X or T1; its existence was classified secret, and speculation began as to its possible origin and probable future.

During the next three years T1 was observed many times, either visually, in the rare clear periods, or by radar, in darkness or under clouds, by aircrews of the 46th Reconnaissance Squadron (VLR) Weather (now the 58th Strategic Reconnaissance Squadron). As T1 continued to move farther from the routine reconnaissance flight paths it was lost for twenty-two months, the last sighting being on 6 October 1949. This last position, 86°05N., 72°00 W., was over 1,400 miles from its first reported position at 76°15N., 160°15W. (see Fig. 3). T1 measures approximately 15 by 18 miles, and in shape resembles an arrowhead or a chicken's heart. No landing was made on T1 and its characteristics were not recorded in great detail.

[1]Ice Reconnaissance Officer, 58th Strategic Reconnaissance Squadron (M) Weather, U.S.A.F.

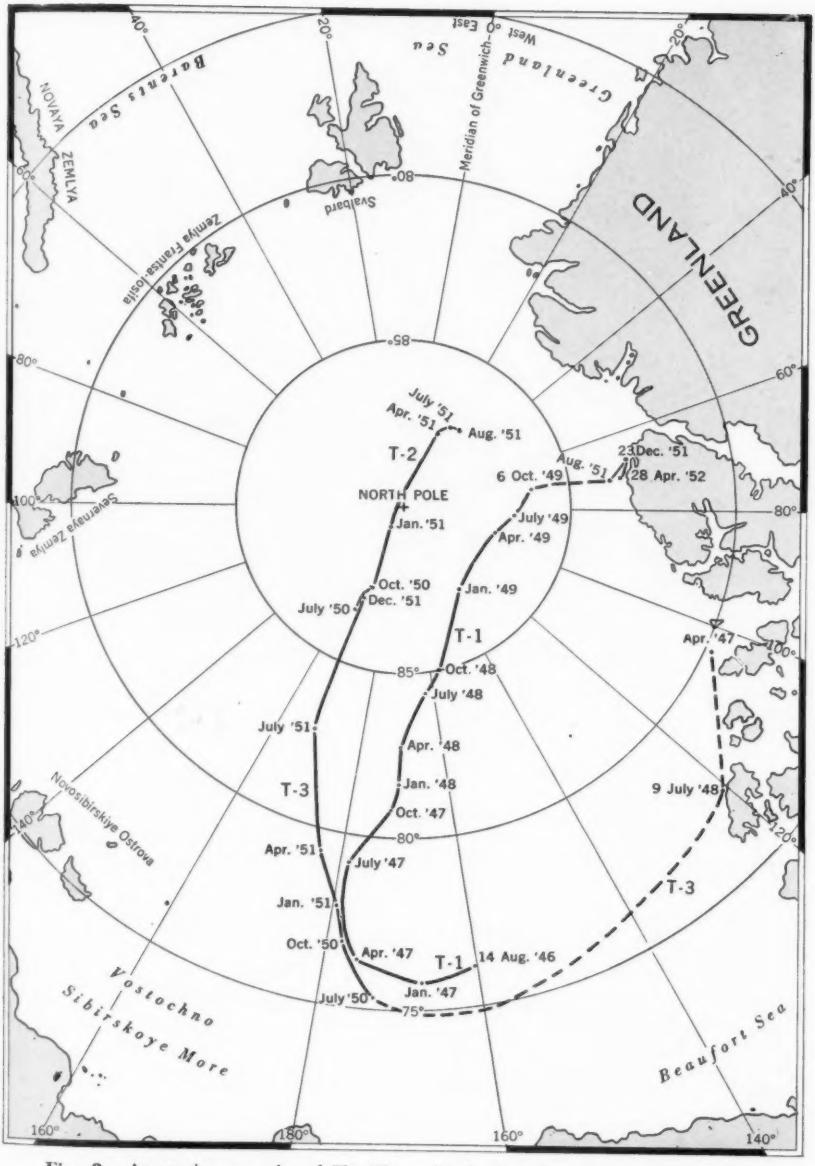

Fig. 3. Approximate paths of T1, T2, and T3 plotted at 3-monthly intervals.

Although routine weather reconnaissance flights were in continuous progress from March 1947, no other ice islands were discovered.[1] This was

[1]The discovery of T3 on a joint U.S.A.F./R.C.A.F. flight in April 1947 was not known to us at this time.

Photo: U.S.A.F.

Fig. 4. T2 from a range of 45 miles, 22 July 1950.

not, however, proof that other ice islands did not exist, for during nearly ten months of the year visual observation of the pack ice is virtually impossible because of darkness or cloud cover.

Beginning in late May 1950 the aircrews of the 58th Strategic Reconnaissance Squadron began a concerted search for other ice islands along the regular Ptarmigan weather flight track north from Alaska, using radar as a primary tool. This search continued without results until 21 July 1950 when a second ice island, T2, about 300 square miles in area, was discovered by visual observation at 86°40N., 167°00E. T2 had, in fact, been discovered and photographed by another aircraft of the U.S.A.F. on 19 July 1950 but had not been reported at the time. At a distance of 75 miles T2 was distinguishable from the surrounding pack ice by a difference in colour. At closer range it stood out by reason of its massive size—17 by 18 miles—and its corrugated surface relief. Parallel troughs ran from one end of the island to the other. They seemed to be filled with water and were connected by what appeared to be streams of running water. (Low-level observations at a later date showed that all these were frozen solid).

Spurred on by the success of July 21 the search was intensified. Our efforts were rewarded when T3 was discovered on 29 July 1950 at 75°24N., 173°00W. Small in comparison with T1 and T2, it was a kidney-shaped ice mass approximately 4.5 by 9 miles. This radar discovery was verified by visual observation on 24 August 1950. On T3 the characteristic ridges and troughs are more pronounced than on T1 or T2.

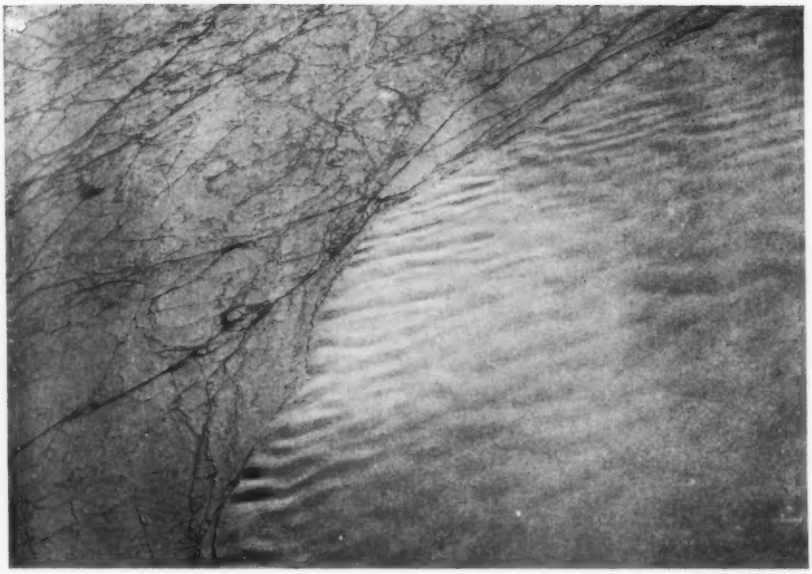

Photo: U.S.A.F.

Fig. 5. Part of T3, showing the difference in surface from the pack ice, 10 May 1951.

In September 1950 ice islands T2 and T3 were the subject of Special Report No. 3, 'Floating islands in the Arctic Ocean', of the 375th Reconnaissance Squadron (VLR) Weather, which formed the basis for Lt. Colonel J. O. Fletcher's paper at the First Alaskan Science Conference. This report left many questions unanswered. To answer some of them, particularly those concerning number and possible places of origin, an extensive reconnaissance program of the Arctic Ocean was planned. It was suggested that the ocean area north of Alaska and the Canadian Archipelago could be searched methodically in conjunction with flying routine weather reconnaissance if the Ptarmigan flight tracks were changed slightly. Fifteen Special Ptarmigan flight tracks were proposed to search the sector of the Arctic Ocean bounded by the 30°W. and the 180°W. meridians, both by radar and by visual observation.

Since the effectiveness of the search depended on visibility below the aircraft flying at about 18,000 feet (500-millibar level), the months of March and April were chosen for the flights to coincide with the period of the year having both daylight and minimum cloudiness. The search began on 14 March 1951 and the ice reconnaissance program continued until April 30, when the last scheduled flight was flown, but no new islands were discovered.

In addition to this series of flights a reconnaissance flight has been made about once a month to keep track of the known ice islands. One of these reconnaissance flights was arranged to explore the land masses bordering the Arctic Ocean from Prince Patrick Island to the eastern shore of Greenland. Photographs and reports from Canadian observers had already suggested that

the ice islands might originate from the north coast of Ellesmere Island. On the night of 19 March 1951 a B-29 aircraft of the 58th Strategic Reconnaissance Squadron (M) Weather took off on Flight Ptarmigan Special Roger. Considerable difficulty, including severe icing over the Brooks Range and adverse winds, prevented complete coverage of the intended track. Nevertheless the flight was far from being a failure. Much of the coastline of Ellesmere Island from Nansen Sound to the turning point at Ward Hunt Island was covered

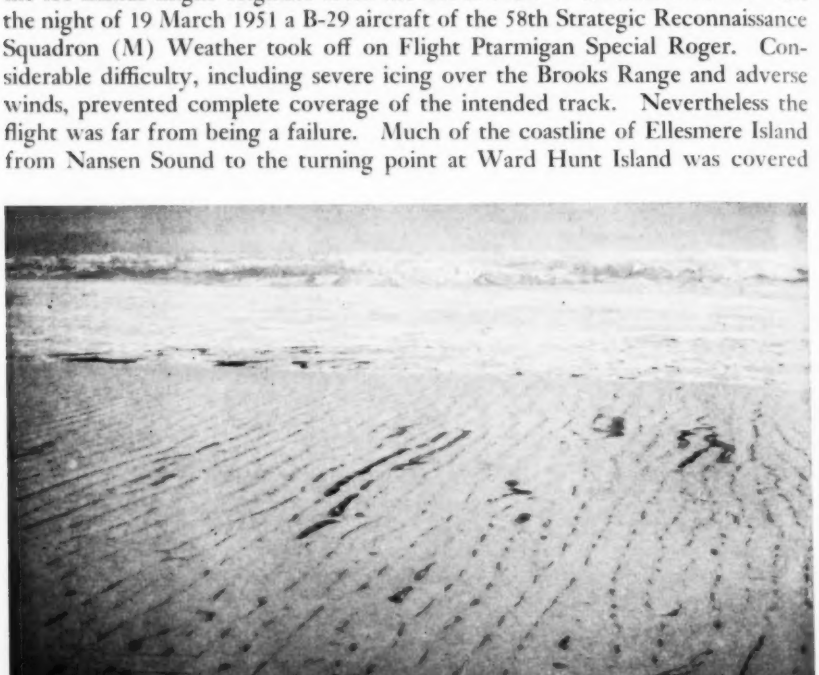

Photo: U.S.A.F.

Fig. 6. Low-level photograph of part of T1, 1 August 1951. The coast of Ellesmere Island in the background, with Ward Hunt Island and Disraeli Bay upper right.

with ridged ice similar to that of T3. This ice also extended up some of the fiords, and photographs were taken of several promising areas. On the return flight a small ice island was discovered in Prince Gustaf Adolf Sea. It was about two miles in diameter, and was almost circular in shape. The success of this flight prompted the squadron to plan a similar flight for later in the season when the effects of the summer melting would be evident.

On 1 August 1951 the weather was excellent and another Ptarmigan Special Roger was flown. Aboard the Weather Reconnaissance B-29 aircraft was a standard crew with the Ice Reconnaissance Officer as Weather Observer, a photographer, and two special observers: Dr. Terris Moore, President of the University of Alaska, and Mr. Maynard W. Miller of the American Geographical Society.

The flight to Ellesmere Island was without incident and the weather continued perfect for visual observation. Most of the coastline was photographed with both still and movie cameras. The ice foot or ice shelf was

more obvious in summer than it had been in March, and extended out from the coast for from five to ten miles. The demarcation line between the solid ridged shelf ice and the loose pack ice was clearly marked. At 73°W. there was a stretch of shelf ice (with Ward Hunt Island in the centre) at least fifty miles long and up to ten miles wide with a surface pattern very similar to that of T3, which unknown to us had been first sighted on a joint U.S.A.F./R.C.A.F. flight in April 1947 about 300 miles west-southwest of this area. As a result of the flight of 1 August 1951 it was concluded that the ice islands could have originated from the ice shelf off the northern shore of Ellesmere Island.

During the approach to Ward Hunt Island a large mass of ice was sighted about fifty miles north of the island. This proved to be T1 which had been lost for twenty-two months. A low-level investigation of the island was made on two runs at approximately 250 feet. The surface was surprisingly flat, with the familiar gently rolling pattern. There appeared to be running water in some of the small transverse drainage channels, but all the water in the large parallel troughs was frozen solid. There was no noticeable change in the size or shape of the island since it was last seen in 1949.

To make the success of the flight complete, T2 was sighted at 87°07N., 25°00W. a few hours after sighting T1 and a low-level investigation was made. T2 has a smoother surface than T1 and the troughs and streams were all frozen solid.

Comments on low-level observations

During the past four years five low-level observations have been made over the three large islands. T1 and T2 were both observed twice, each time in the month of August. Crew members were amazed at the smoothness of the surface and the absence of water compared with the surrounding pack ice. From 100 feet it could be seen that the crests of the ridges are only 2 to 3 feet higher than the troughs on T1, and only inches higher than the troughs on T2. Maynard M. Miller's comment sums up our observations: "By low level flying, we were able to observe how incredibly smooth T2 was. (T1 was slightly rougher). This smoothness can perhaps be explained by the fact that melt-water—both from surface ablation and from that flowing in stream channels . . . becomes impounded in the linear lows during the summer months. . . . In late summer or autumn, such melt-water refreezes and the relief of the 'undulated structure' is consequently reduced. This process can be repeated, perhaps without all of the blue ice frozen during the previous year becoming melt again in subsequent seasons. (This could happen especially if the 'island' broke out and drifted to more northerly climes). At any rate, it is possible to visualize a progressive cycle of melting and freezing, which not only tends to level the surface, but also to add considerable structural strength to the overall mass." (Fletcher and Koenig, 1951, p. 25).

T3 was observed from low level during the month of May 1951 before any melting could have taken place. The entire island was covered with a layer of snow. The rolls were much more pronounced than on T1 or T2,

yet the surface was still relatively smooth parallel to the troughs and crests. T3 has a more marked resemblance to the shelf ice of north Ellesmere Island than T1 or T2, which appear to have weathered considerably.

Pilots who have made the low-level flights were almost unanimous in stating that an emergency landing could be made safely on all three ice islands, especially T2.

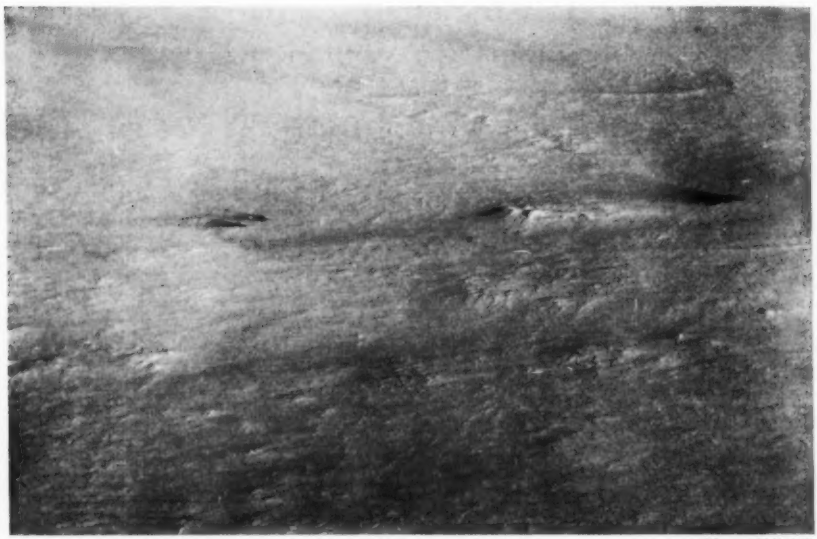

Photo: U.S.A.F.

Fig. 7. T3 under snow from 250 feet, showing mounds probably of morainic material (cf. Fig. 16), 10 May 1951. From this altitude the undulations are barely perceptible.

Movements of the ice islands

The movements of T1, T2, and T3 are shown on Fig. 3. The somewhat erratic paths followed by these islands have been smoothed out to compensate for navigational errors. Celestial navigational fixes are often impossible in high latitudes because of daylight or twilight conditions.

Over a period of thirty-eight months (14 August 1946 to 6 October 1949) during which T1 was followed with some regularity, the island moved a distance of some 1,400 miles, giving an average rate of approximately 1.2 mile per day. As there is no record of the movement from 6 October 1949 to 1 August 1951, the recent positions were not included in the calculations.

T2 has been observed for a much shorter period than T1, and our figures on the movement of this island cover only fifty-seven weeks. During this time T2 was north of 86°N. and moved approximately 460 miles at a rate of 1.1 mile per day.

During the fifty-four weeks that T3 has been under continuous observation (from 4 December 1950 to 18 December 1951) it has moved approximately 500 miles at a rate of 1.3 mile per day. For a period of thirty-nine

months (from 27 April 1947 to 29 July 1950) T3 moved from a point about forty miles north of Cape Isachsen to a position at 75°30N., 175°00W. The only intermediate observation was at 77°15N., 121°00W., near the west coast of Prince Patrick Island. Assuming a movement shown by the dashed line on Fig. 3, T3 would have moved approximately 1,200 miles at a rate of 1.0 mile per day, which seems a reasonable figure.

From Fig. 3 it is noticeable that there is a northerly movement of the islands once they reach 175°W.; there also seems to be a definite slowing down in movement when they reach the area north of Greenland; and finally it appears that there must be some current that originally brought them from the region of Ellesmere Island and Greenland to the area north of Point Barrow.

Visual observations and radar sightings have shown that the ice islands frequently have open water at one or more sides. This is the case even when there is no open water elsewhere in the immediate vicinity. This suggests a movement differential between the ice islands and the pack ice. It is well known that icebergs move with the ocean currents rather than with the winds which move the pack ice. Ice islands would presumably behave like icebergs and their movements should therefore be a valuable assistance in determining the direction and rate of the subsurface currents in the Arctic Ocean because they are so easily seen and recognized.

We may conclude that in the period of one to three years during which the three large ice islands have been under regular observation they have moved at a rate of approximately 1.2 mile a day, and have followed what appears to be a circular track from north Ellesmere Island along the edge of the Canadian Archipelago to about 75°00N., thence west to 175°00W., and northwards across the region of the north pole.

Part II. Additional information from Flights and Air Photographs in the Canadian Arctic. *By Squadron-Leader K. R. Greenaway, R.C.A.F.*[1]

The interest aroused by the work of the U.S.A.F. in plotting the courses of T1, T2, and T3, and by the photographs taken of the three islands, led to a re-examination of certain photographs taken on flights in the Canadian Arctic. On 27 April 1947, in the course of a joint U.S.A.F./R.C.A.F. flight, a large ice floe with an unusual rippled surface pattern was photographed by the writer at 79°50N., 104°00W., 30 miles north of Isachsen Peninsula, Ellef Ringnes Island. There was considerable discussion at the time as to its origin. Similar ice, attached to the shore, had been seen and photographed by the same crew on the north coast of Ellesmere Island three days earlier, and it was therefore decided that the floe was a piece of land-fast ice, very possibly from north Ellesmere Island, which had broken off and was drifting with the pack. On comparing the photograph with those of the three Ts it was found that it was clearly identifiable as T3. An ice island photographed

[1]Arctic Section, Defence Research Board, Canada.

Photo: U.S.A.F.

Fig. 8. Ice island off Cape Columbia, July 1947. This island must have broken away from the shelf ice shown in Fig. 9. The apparently greater relief of the island is due to meltwater in the furrows at the end of July while the shelf ice in the June photograph is still snow-covered.

on 9 July 1948 from a U.S.A.F. aircraft engaged in survey photography under a joint Canadian/U.S. agreement also turned out to be T3. At this date its position was 77°15N., 121°00W., near the west coast of Prince Patrick Island. Thus three years were added to the known life of T3, which was first seen by the 58th Strategic Reconnaissance Squadron, U.S.A.F. on 29 July 1950.

The U.S.A.F. survey photo flights revealed two further ice islands in the Arctic Ocean, neither of which can be identified as any of the three Ts. One was photographed on 28 June 1948 at 82°45N., 104°30W., about 100 miles northwest of Cape Stallworthy, Axel Heiberg Island. This island, which has not been seen since, was about 7–8 miles long and 6–7 miles wide.[1]

The other island, which has also been "lost" since 1948, is of very special interest because the photographs reveal not only the island but also the place from which it apparently came. It was first photographed in July 1947 about 5 to 10 miles from the north coast of Ellesmere Island off Cape Columbia, at approximately 83°10N., 70°00W. (Fig. 8).[2] The same series of photographs shows a place near Cape Nares where a large section of the shelf ice appears to have broken away and into which two sides of the ice island could be fitted like a piece of a jig-saw puzzle. The space had been filled with

[1]It is possible that this may be the same island seen by the U.S.A.F. near T3 in March 1952.

[2]This island is shown on the Robeson Channel (No. 8) World Aeronautical Chart. The smaller island lying to its east could not be found on a careful search of the air photographs.

ordinary smooth fast ice, and the outline of the broken edge had not changed when the R.C.A.F. photographed the coast in June 1950 (Fig. 9). The surface of this island was very similar to that of T1 and it was about the same size and therefore one of the largest seen up to the present time. It was photographed again in May 1948, when it was 20 miles east of its previous position and about the same distance from the coast. Assuming a constant rate of drift, it is very likely that the island broke away from the shelf ice in 1946. It is interesting to note that this island was moving eastward. T1, which also drifted east in the same area but a little farther offshore, appears now to be moving slowly westward.

T1 was sighted by the 58th Strategic Reconnaissance Squadron, U.S.A.F. on 23 December 1951 a few miles off the coast of Ellesmere Island. On 28 April 1952 a Lancaster from the R.C.A.F. Central Navigation School sighted it about 50 miles west of this position, at 83°25N., 72°00W. Its shape had

Photo: R.C.A.F.

Fig. 9. Shelf ice off Cape Nares, June 1950, showing a jagged line marking where the island in Fig. 8 has broken away. The gap left has been filled with smooth fast ice.

remained unchanged, but timed runs across the island suggested that it was about 17 miles long and 13 miles wide, slightly smaller than previously reported. Its surface appeared to be very smooth and it was considered that in an emergency it would be perfectly practicable to make a "wheels down" landing. Pack ice in the form of pressure ridges was piled up to a height of about 10 to 15 feet around its edges. No part of the island's edge protruded above the surrounding pack; it is very doubtful if the total thickness of the ice exceeds 70 feet.

When looking through some of the R.C.A.F. trimetrogon photographs of the Canadian Arctic Islands a few smaller ice islands had from time to time been noted. A more thorough search was therefore undertaken. As a result twenty-eight ice islands, varying in size from a quarter of a mile to 7 or 8 miles across were found, as well as a considerable number of smaller fragments. They were distributed as follows:—

Arctic Ocean: 3

An ice island about 6 by 3 miles in area appears in photographs taken in the summer of 1950 about 10 miles east of Alert Point, Ellesmere Island. It is on the very edge of the pack ice. Two smaller islands are near it. A few others were found among the fast ice on the north coast of Ellesmere Island, but as they have not yet broken loose they have not been counted.

Nansen Sound–Eureka Sound: 3

Three ice islands were discovered on the photographs of the Nansen Sound–Eureka Sound area, all taken in July 1950. One was at the entrance to Nansen Sound, at 81°33N., 92°40W. This island was 3 miles long and 2 miles wide and had a curious vermicular pattern quite unlike any of the others (Fig. 13). The second and smallest island, 2 miles long and a little over one mile wide, was in Eureka Sound just north of the entrance to Slidre Fiord. The third was larger than the other two, about 5½ by 3 miles, and was between the eastern end of Stor Island and the Ellesmere Island coast (Fig. 17). This island was recognized as one that had appeared on the U.S.A.F. survey photographs taken in the summer of 1948, when it was in Nansen Sound near the entrance to Otto Fiord. It had thus moved about 120 miles in two years. In late August 1950, shortly after the air photograph was taken, the icebreaker U.S.C.G.C. *Eastwind* attempted without success to force a passage through the island on her way to resupply Eureka Weather Station. Fortunately, Eric Fry of the Canadian Topographical Survey, an observer on the icebreaker, took several photographs of the island (Fig. 16). Before the landing on T3 these were the only photographs of an ice island taken from the surface. The flatness of the ice surface in these photographs is most striking, as from the air the island appears to be one of the roughest. It was thought that it might be aground on Stor Island, but another photo line flown in 1951 showed that it was no longer there.

Peary Channel: 5

A group of five islands, three of which were about 1 mile square and the other two somewhat smaller, appear on photographs taken in July 1950 at 79°05N., 96°30W., some 15 miles north of Amund Ringnes Island.

Prince Gustaf Adolf Sea: 1

Photographs taken in July 1950 show a small island midway between Cape Malloch, Borden Island, and Cape Isachsen, Ellef Ringnes Island. It was about

Fig. 10. Ice islands shown on air photographs in the Canadian Archipelago. The areas of the islands are not correct for scale, but do give their approximate relative sizes.

Photo: R.C.A.F.

Fig. 11. A small ice island in Maclean Strait, taken in August 1950.

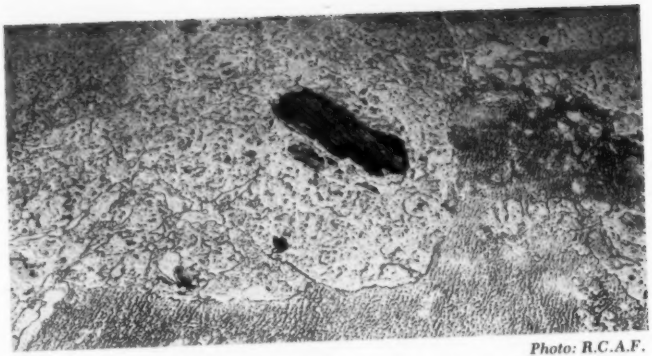

Photo: R.C.A.F.

Fig. 12. The same ice island from the other side, taken in July 1951, 60 miles from its former position.

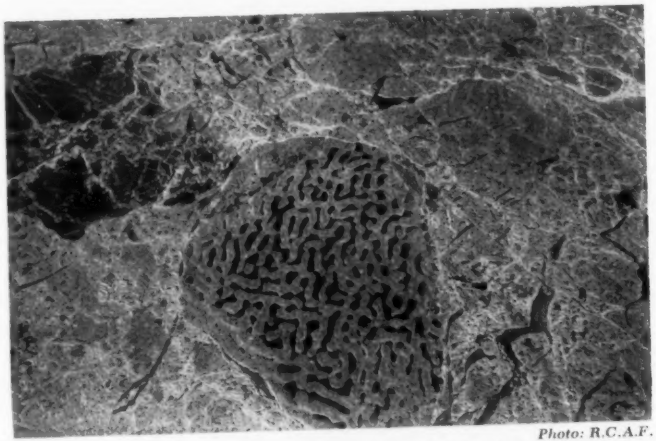

Photo: R.C.A.F.

Fig. 13. Near the entrance to Nansen Sound, July 1950. The surface pattern of this ice island is very unusual.

Photo: R.C.A.F.

Fig. 14. Ice island in Peel Sound just north of Bellot Strait, August 1950.

2 miles square. In March 1951 the 58th Strategic Reconnaissance Squadron, U.S.A.F. reported seeing an ice island in this area, and it is possible it may be the same one, but the R.C.A.F. photographs are taken from too great a distance to allow a satisfactory comparison.

Maclean Strait: 3

A small ice island about 1½ mile long by ½ mile wide is shown on photographs taken in August 1950 and in July 1951. In the course of this time it moved from 77°56N., 105°30W., ten miles north of Lougheed Island, to 77°08N., 102°30W., 20 miles east of Edmund Walker Island. This represents a straight line distance of 60 miles in a southerly direction. A small fragment which lies a few yards off the southeast side of the island in the earlier photographs is still in the same relative position in the later ones. Indeed quite a large section of the pack seems to have moved as one whole (Figs. 11 and 12). Two other islands were photographed in 1951, one at 76°54N., 102°50W., and one 10 miles off the southwest corner of King Christian Island. Both were about half a mile square, and there were two fragments lying off the southeast corner of the second one.

Byam Martin Channel: 1

An ice island measuring 5 by 2 miles appears on photographs taken in August 1950 east of Sabine Peninsula, at 76°30N., 106°30W.

Hecla and Griper Bay: 4

One of these islands, 4 by 2 to 3 miles in area, appears on two photographs, one taken in July 1948 and the other in August 1950. In both its position is the same, 76°20N., 113°30W. off Cape Grassy about 4 miles east of Depot Island. It may be aground, but it is likely that the ice in the bay has not broken up during this period. The island has a very flat, worn down surface. The other three islands, all of which appear on August 1950 photographs, were much smaller, only about half a mile square. Their positions were: 76°22N., 111°50W.; 76°30N., 111°25W.; and 76°45N., 112°00W.

Peel Sound: 1

An ice island about 2½ miles square appears on photographs taken in August 1950 approximately 1½ mile offshore 3 miles north of the western entrance to Bellot Strait (Fig. 14).

James Ross Strait: 3

On photographs taken in August 1951 three islands were found close together between Cape Felix, King William Island, and Cape Adelaide Regina, Boothia Peninsula. One was about 3 miles square and the others about ¾ mile square and 1 by ¼ mile respectively. The large one was not the same as the one photographed in Peel Sound the year before.

Victoria Strait: 4

This is the farthest south that ice islands have been found. Photographs taken in August 1949 reveal one large and three small islands in Erebus Bay on the west coast of King William Island. The large one was about 3 miles square and the smallest 1 mile by ¼ mile. There were also a large number of fragments, many of them long slivers which were easily distinguishable from the surrounding loose brash ice (Fig. 15). It appears as if the large island is breaking up and the slivers have broken off parallel to the ridged pattern.

In addition to these twenty-eight ice islands two rather similar ones were found in *Greely Fiord*, which however appeared to be of local origin. Photographs taken in July 1950 show one of them, 1½ by ¾ mile in size, at about 80°50N., 77°30W.

Fig. 13. Near the entrance to Nansen Sound, July 1950. The surface pattern of this ice island is very unusual. *Photo: R.C.A.F.*

Fig. 14. Ice island in Peel Sound just north of Bellot Strait, August 1950.

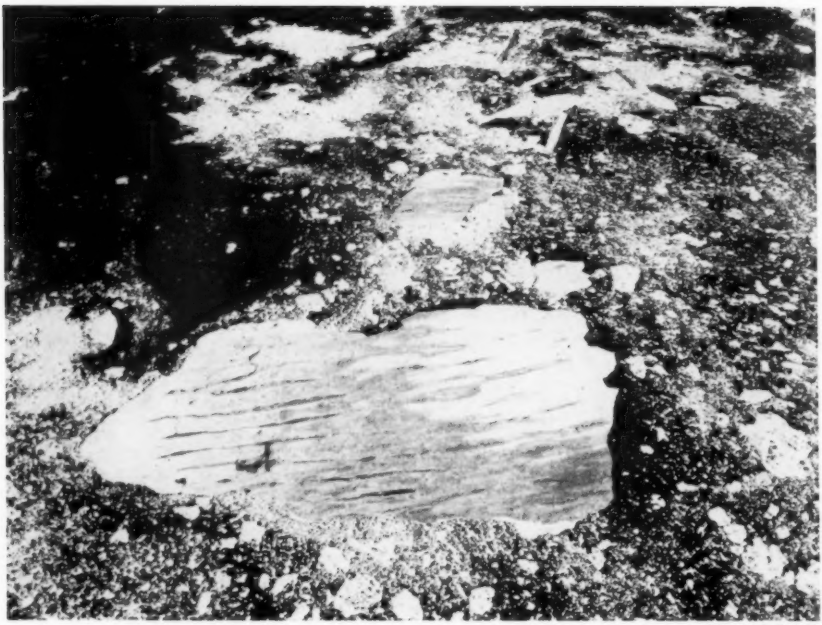

Photo: R.C.A.F.

Fig. 15. Ice island in Victoria Strait, August 1949. A smaller island is beyond it and also several slivers which have probably broken off it.

Photographs taken in July 1947 show the same piece of ice in the process of breaking away from a glacier at the head of Antoinette Bay. The same photographs show another island (or berg) about the same size in the central part of the fiord. These resemble ice islands in every way except that the surface pattern is more confused and lacks any suggestion of the characteristic parallel ridges.

There are no doubt other islands to be found on the trimetrogon photographs. The search carried out was by no means exhaustive, though good coverage was given to the most likely areas. Moreover, photographs are not available of all water areas. No flight lines, for instance, cross M'Clure Strait or Melville Sound, and the coverage of M'Clintock Channel is far from good. It is felt, however, that most of the islands shown in the photographs have been spotted.

No ice islands were found in the channels to the east of Ellesmere Island, though it might seem probable that some would drift eastward and down Robeson Channel. Nor were any found in M'Clure Strait, though owing to poor coverage this does not necessarily mean very much. It is likely though that those that reach Prince Patrick Island without being drawn into the archipelago are more apt to be carried out into the Arctic Ocean than into M'Clure Strait. The general movement within the archipelago is, as might be expected, south and southeast.

Part III. Historical references to Ice Islands. *By Moira Dunbar*[1]

The name "ice island" is by no means a new one. It has been used from the very earliest times to describe a wide variety of phenomena. Frobisher and Baffin, for instance, both speak of "Ilands of Yce". From the accompanying description it is quite clear that they mean icebergs. Among later writers, de Long uses the term to describe detached floes which his party used to ferry themselves and their equipment across open leads during their summer retreat from the wrecked *Jeannette*. In this case, of course, it is used merely as a handy descriptive phrase and is not intended to be taken as a technical term. There is, however, one technical use which should be mentioned, although it applies only to the Antarctic. Wright and Priestley use the term "ice island" to describe a certain type of tabular berg which is roughly conical in shape and looks very like an ice-covered island with high ground in the middle of it.

To trace the use of a name, however, is one thing; to trace the occurrence of a particular type of ice is quite another. The traveller cannot bring back samples of the ice he sees, nor as a rule can he state with any degree of certainty that the ice he has described is in such and such a position and may be seen by anyone who cares to go and look. This has led to confusion of terminology and it is sometimes hard to correlate the accounts of different observers.

It is therefore not possible to say with certainty that ice islands have been seen by earlier explorers. Any old ice, whether it be glacial ice or rafted sea ice, will display some of the characteristics of the ice islands, and as study of them by living observers has so far been almost exclusively from the air, it is not yet known whether they stand out as clearly to the ground traveller as they do from the air. From the only available photographs taken from ground level it would appear that they may look much flatter than they do from the air. The island in Figs. 16 and 17 looks very uneven in the air photograph, but on the ground flat, though rough. This is probably because the distance between the crests is long and the slopes generally gradual, so that it may be necessary to have the perspective of height in order to see the pattern.

There are, however, many descriptions of ice that might very well be of the same formation as the ice islands. There are also very good descriptions of the ice in the probable source area on the north coast of Ellesmere Island from the two parties that have sledged over it.

Parry, on his first voyage in 1819-20, describes a large floe in M'Clure Strait which sounds temptingly like an ice island: "an immense floe which formed the principal, or at least the nearest, obstruction to the westward, was covered with large hummocks, giving to its upper surface the appearance of hill and dale. . . The thickness of this floe at its nearest edge was six or seven feet above the sea, and as about six-sevenths are usually immersed, the whole thickness would appear, in the common way of reckoning it, to have been

[1]Arctic Section, Defence Research Board, Canada.

Photo: Topographical Survey of Canada

Fig. 16. Ground level view of the south end of an ice island in Eureka Sound off Stor Island, showing moraines and melt pools, August 1950. Compare the flatness of the ice surface with the rough appearance of Fig. 17.

Photo: R.C.A.F.

Fig. 17. Vertical air photograph of the north end of the island in Fig. 16, July 1950. Stor Island to the left.

from forty to fifty feet. . . But the hummocks were many of them at least from fifteen to twenty-five feet above the sea; so that the solidity and thickness of this enormous floe must have been infinitely greater than any thing we had seen before." (Parry, 1821, p. 240). From the accompanying sketch, however, it seems more likely that this was a large rafted and hummocked old floe, possibly formed on the west coast of Banks or Prince Patrick islands, where the pressure from the arctic pack is very heavy. Similar ice in the same area is described by Robert S. Janes, Second Officer of the D.G.S. *Arctic* on Bernier's voyage of 1910, about thirty miles south of Cape Providence: "Now when I say floe I mean in this case that it was something unusual for I never saw such ice; it must have been 50 to 60 feet thick with hills on it as high as any berg. One saw in coming around this floe it was unbroken, it must have been as old as Adam." (Rep. on Dom. Gov. Exped. (1912?) p. 30). Such references could be quoted indefinitely, especially from travellers off the west coast of Banks Island. But these do not appear to be the ice islands of the air photographs. Isaac Hayes, who sledged across Kane Basin from Etah to Dobbin Bay in 1861, describes "an old field" that he measured as follows: "Its average height was twenty feet above the sea level, and about six by four miles in extent of surface, which was very uneven, rising into rounded hillocks as much as eighty feet in height, and sinking into deep and tortuous valleys." (Hayes, 1867, p. 311). This may well have been one of the flat-topped bergs (Fig. 18) which still break off some of the glaciers in eastern Ellesmere Island.[1] On the other hand it may have been an old arctic floe that had drifted down Robeson Channel, or it may have been an ice island. The chief argument against the likelihood of any of these being ice islands is the apparent roughness and variety of the topography described within a small area.

The expeditions of Nares (1875-6) and Greely (1881-4) did much to add to the general knowledge of both sea and glacier ice and also much to confuse the terminology. This confusion is largely connected with the use of the term "palæocrystic", a word coined by Nares to describe the heavy old pack ice of the Arctic Ocean (Markham, 1878, p. 228). Almost every north polar traveller since then has used this term, but not always to describe the same thing, and as many do not define what they mean by it, the reader is left to make his own interpretations.

Nares's expedition also coined the term "floeberg". By this was meant, as is sufficiently clear from the description and from a photograph which appears in Nares's book, large blocks of polar pack ice which have been thrust up on end by pressure and which commonly mark the junction between the fast ice and the pack; hence the name "Floeberg Beach" which he gave to the *Alert*'s winter quarters because of the line of grounded "floebergs" which protected the ship from the moving pack. He uses the same word to describe the large flat-topped bergs which he saw in Robeson Channel and farther south, which he considered to have the same origin.

[1]And possibly off some of the glaciers of northwestern Greenland.

Greely saw what he thought to be similar "palæocrystic floebergs" in the channels between Ellesmere Island and Greenland and decided that they were of glacial origin and that some of them at any rate came from the east Ellesmere Island glaciers, which produced flat-topped bergs because they had more gradual terminal gradients than the Greenland glaciers south of 80°N. Through his assumption that they were the same as Nares's floebergs he complicated the issue by introducing a suggestion of glacial origin for palæocrystic ice. At the same time he also used the term "palæocrystic" to describe floes in the polar pack which he believed to be ordinary sea ice, and called the whole "palæocrystic pack". From this confusion the term has never recovered. Perhaps the best definition is that of Lauge Koch (1928, pp. 388-92) who follows the usage of Nares and suggests that this ice is formed by rafting, hummocking, and snow accumulation. He limits the area of its occurrence to the seas north of Greenland and the Canadian islands and south of Peary's "Big Lead".[1] The ice north of this lead drifts freely to the open sea east of Greenland, but that to the south is pressed against the land masses and therefore subjected to heavy pressure. It thus attains great thickness and may remain for very many years before melting or escaping to the south through Robeson Channel.

Greely has much that is interesting to say about ice. He divides his "palæocrystic" ice of the channels south of the Lincoln Sea into floes and floebergs, both of which he considered to be of glacial origin, noting their likeness to descriptions of the antarctic shelf ice by the Challenger Expedition. He goes so far as to postulate the existence of an arctic ice cap similar to that of the Antarctic. The floes he describes as ranging from twenty to fifty feet in thickness, and from thirty square yards to as many square miles in area. "On leaving Cape Baird, in August, 1883, my diary records a palæocrystic floe which was fifteen miles long and of unknown width. Another floe, between Cape Beechy and Cape Sumner, was of such extent that a sledge party was nearly two days passing over it. The surface of such a floe resembles closely a piece of rolling country. It is by no means level, but has its hills and dales, its water-courses and lakes; in fact, it is an island where ice replaces earth." (Greely, 1886, Vol. 2, p. 46). This description sounds remarkably like an ice island.

The floebergs are described by Greely as huge, cubical blocks of ice "of a vertical height of from fifty to eight hundred feet, and having sides varying from twenty to a thousand feet in length. The largest one seen by me was about eight hundred feet high, (nearly ninety feet above the sea,) six hundred feet broad, and nine hundred feet wide, nearly a perfect cube." (Vol. 2, p. 47). The ice of these bergs was very clearly stratified, but morainic material was rare. This Greely considered quite natural, as the glaciers of Grinnell Land were also observed to be remarkably free from such matter. He does describe one morainic deposit, however, on the top of a very large floeberg to which he was able to climb over "piles of heaped up ice. Its surface was very

[1]An open lead encountered by Peary on all his polar attempts at about 84°30N. Flights over the Arctic Ocean confirm that a lead is very frequently seen in this area.

Photo: R.C.A.F.

Fig. 18. Dobbin Bay, east Ellesmere Island, showing glaciers and their flat-topped bergs, 24 June 1950. Note the tributary glacier upper left which no longer joins the main one, and the apparently inactive glacier at lower left.

diversified, there being two valleys. . . . This block of ice, six hundred feet thick and nine hundred square, was a floeberg or flat-topped iceberg which had floated from Kennedy Channel with us. In crossing one of the valleys, my foot displacing a thin coat of lately fallen snow, I accidentally discovered a rock. Examining farther I found two rocks and boulders, one in each valley. There were not far from fifty such rocks, and it was evident that they were medial moraines." (Vol. 2, p. 53).

Greely considered that the largest of these floebergs came from the Arctic Ocean, from his supposed arctic ice cap. It is not at all improbable that they were fragments of the northern Ellesmere Island shelf ice. The estimated thickness of six hundred feet is certainly much greater than that of any of the islands known today, but this might be accounted for to a certain extent by wasting in the intervening period. It is also possible that the thickness was over-estimated. It is very hard to estimate vertical distance accurately, and as the visible part of a berg is small compared with the subsurface part a small error would be multiplied considerably in calculating the total thickness. Smaller floebergs, though "of no inconsiderable size", were observed by Greely and others of his party having apparently broken off from glaciers in eastern

Ellesmere Island. Among the places where he mentions seeing them is Dobbin Bay, and a great many are still there today (Fig. 18). As the glaciers of Ellesmere Island were in all probability much more active then than they are now it is not surprising that Greely found these floebergs so common.

Lockwood noticed similar flat-topped bergs coming from the glaciers at the head of Greely Fiord: "Many small icebergs were seen at the head of Greely Fiord in both the bays, as well as an occasional stray one farther down. They were, so far as I could judge, entirely similar to the ordinary floeberg of the straits (Robeson and Kennedy Channels). . ." (Greely, 1886, Vol. 2, p. 55). Two of these bergs appear on recent air photographs of Greely Fiord.

G. W. de Long, in 1881, retreating towards the Lena delta after the wreck of the *Jeannette*, came upon "some very old heavy ice, dirty and discolored with mud, with here and there a mussel shell, and with a piece of rock on it, which, as it was similar to that on Henrietta Island, I carried along." (Emma de Long (ed), 1884, p. 613). "I measured one place and found it thirty-two feet nine inches thick, and where it is not mud-stained it is rounded up in hummocks resembling alabaster." (p. 614).

Nansen apparently found nothing with strongly marked ice island characteristics during the *Fram* expedition. The nearest description we find is of "massive high hummocks with . . . square sides, and of great circumference, sometimes quite resembling snow-covered islands. They are of 'palæocrystic ice', as good as any one can wish." (Nansen, 1897, Vol. 2, p. 184).

Otto Sverdrup, whose expedition of 1898-1902 mapped the west coast of Ellesmere Island and added Axel Heiberg and the Ringnes islands to the map, mentions some "old polar ice" in Eureka Sound "with enormously high melted-off ridges and deep dales, where the snow was as loose as sand." (Sverdrup, 1904, Vol. 2, p. 192). Describing Isachsen's journey round Ellef Ringnes Island, he writes: "The most western and north-western parts of 'Isachsen Land' were also low, a land of sandbanks. On its west side the ice was coarse and pressed up in wave-like, more or less parallel, ridges. Violent upheaval must have taken place here, for ridges several yards in height lay pressed right up on land." (Vol. 2, p. 297). Both these descriptions might refer to ice islands.

Storkerson, of the Canadian Arctic Expedition, drifted on an ice floe in the Beaufort Sea with a party of four from April to October 1918. The floe on which they made this drift is one of the most probable ice islands in the literature, as is plain from the following description.

"The floe at the northern edge of which our camp was situated and on which we drifted through the summer of 1918 from the 8th of April to the 9th of October, can best be described as a large island of ice about seven miles wide and at least 15 miles long. This latter estimate is less than the real length of the floe but I say 15 miles because I only explored 15 miles of it. It may have been 30 miles long for all I know. In relation to the smaller surrounding floes it acted exactly as land does. The smaller floes would be more affected by the winds and would drift faster back and forth, depending on the direction of the winds. This fact was of great advantage to us in that with west wind

we would have open water to the east. The smaller floes would drift away from the point at which we had our camp. With east wind the small ice on the west side would drift to the west, so we nearly always had open water in which to hunt seals.

"From an elevation close by our camp the panorama presenting itself impressed me exactly as that of a certain kind of land. The colour of course was the bluish white of ice but the contour of the hills, the ridges and the levels in between and in which numerous small lakes and ponds were visible, was exactly like certain stretches of prairie I have seen in the midwestern United States and Canada. This similarity of old ice to land is well known.

"The thickness of the ice at our camp, judging by the amount of it visible above the level of the sea, I should say would be about 50 or 60 feet. This extraordinary thickness was just local and the average of the whole floe naturally would be much less, probably less than 20 feet." (*in* Stefansson, 1921, p. 699).

The statement concerning the well-known resemblance of old ice to land is a timely warning against over-eager diagnosis of ice islands. Nevertheless the size and thickness of this floe combined with its topography strongly suggest an ice island, and the area of the drift was only about 120 miles from the place where T1 was observed in the fall of 1946. It is also interesting to note that Major Koenig reports that T1, T2, and T3 appear to move at a different rate from the surrounding pack and very commonly have open water on one side. This seems to support the suggestion that they are influenced more by current than wind, and certainly their northward track towards the pole is directly against the prevailing winds.

Two interesting references come from the Arctic Ocean sledge journeys of Peary in 1906 and of Frederick Cook in 1908. Peary, somewhere about 86°N., "traversed several large level old floes, which my Eskimos at once remarked, looked as if they did not move even in summer. . . . Several berg-like pieces of ice discoloured with sand were noted during the march, my Eskimos saying that these looked as if we were near land." (Peary, 1907, p. 131). Cook, who, however far he was from the pole, undoubtedly sledged a considerable distance over the Arctic Ocean, provides one of the most likely of all historical references to ice islands: "from the eighty-seventh to the eighty-eighth parallel we passed for two days over old ice without pressure lines or hummocks. There was no discernable line of demarcation to indicate separate fields, and it was quite impossible to determine whether we were on land or sea ice. The barometer indicated no perceptible elevation, but the ice had the hard, wavering surface of glacial ice, with only superficial crevasses." (Cook, 1911, p. 265).

Both these instances are quoted by E. S. Balch in 'The north pole and Bradley Land' as evidence to prove the existence of Bradley Land, seen by Cook in 1908, and Crocker Land, reported by Peary in 1906. These lands turned out to be fictitious and the many flights over the Arctic Ocean leave no possibility of their existence. They apparently belong to the ranks of imaginary polar islands which include the Russian Sannikov Land, Keenan

Photo: R.C.A.F.

Fig. 19. Vertical air photograph of old ice floes in Smith Sound, 24 June 1950. The uneven worn down topography of such floes might easily give rise to descriptions by ground travellers that sound like ice islands.

Land in the Beaufort Sea, and Presidents Land, reported by the *Polaris* party in the Lincoln Sea in 1871. It is pleasant to think that at least some of these might have been ice islands, their height exaggerated by the well known polar mirage effect. The mountainous topography described by Cook makes this improbable in the case of Bradley Land, though an alleged photograph of it in his book looks less dramatic than his description. Peary's "snow-clad summits of a distant land" sounds more likely but this may be simply because the description is less detailed.

Another reported land which appears not to exist is Takpuk Island in the Beaufort Sea, "discovered" in September 1931 by an Eskimo, Takpuk, in his schooner of the same name. This island is well documented, as the discoverers landed on it and took several photographs. As described by Stefansson (1934, p. 104) it was about "half a mile long and of nearly the same width, but with

an irregular outline. . . The island was highest at the south-eastern end, sloping towards the northwest. The hill (at the southeastern end of the island) was about as high as the highest land on the shore line near Barrow, which is Cape Smythe, about forty or fifty feet above sea level. The surface was rolling, and there were small ponds." The schooner approached the island through deep water, and with her bows against the beach had a depth off her stern of twenty fathoms. Takpuk is described as being a very fine type of Eskimo with " a most excellent reputation for truthfulness". He had no way of checking the exact position of the island, but had apparently worked well offshore from the coastal fringe of islands. From the available evidence, Stefansson placed its position as near 71°20N., 145°30W. At that time, before aircraft became a familiar means of arctic transportation, there was no reason why a new island should not be found in the Beaufort Sea. Since then there have been many flights over the area and some hydrographic work, and as Takpuk's island has not been reported it may be presumed not to exist.

The evidence in favour of its having been a small ice island is impressive. At first sight the photographs showing the "hill"—a rounded cone of what appears to be coarse unconsolidated material of the boulder clay type—and a quite large area covered all over with earth, seemed to rule out the possibility. A comparison with Eric Fry's photographs of the island in Eureka Sound, however, reveal a quite striking resemblance, particularly in the hill and the ponds (Fig. 16). The soil-covered area is certainly much larger, and grass and mosses were reported on Takpuk's island, but neither of these phenomena seems impossible on an ice island. The description of its surface characteristics and the deep water offshore are strong evidence in favour of the theory. Finally the position is not so very far from the known track of T1.

Stefansson, in 'The friendly Arctic', mentions a small island discovered by Emiu, an Eskimo of his party, "lying . . . perhaps ten miles southeast from the middle of the east coast of Emerald Isle". (p. 492). The air photographs reveal no island in this position. As Stefansson gives no details, the question of its having been an ice island must remain a matter of pure speculation. The area however is one where small ice islands are quite common today.

Edward Shackleton, sledging over the entrance to Dobbin Bay in 1935, "crossed a huge palæocrystic floe, tremendously thick and worn and weathered during countless years, into an undulating country of miniature hills and valleys. On this the snow was packed much harder, and for several hours we made good progress, driving up and down hill until we were nearly half-way across Dobbin Bay." (1936, p. 413). This description might equally well fit an ice island or a very old floe such as is shown in Fig. 19 in much the same area.

The most recent reference to possible ice islands comes from Russia. "In October 1943, three kilometres to the north-northwest of Mys Chelyuskin, a flat-topped iceberg was discovered, 1,500 metres long, 400 metres wide and rising 10 metres high out of the sea. As the fliers informed me, they sighted this unusual ice-mesa off the eastern coast of Severnaya Zemlya during ice reconnaissance flights." (Zubov, 1948). Zubov also reports that icebergs were

seen off the east coast of Ostrov Vrangelya in 1946, aground in shoal water, and off the west coast of the island in 1947. No bergs had ever been seen in this area before, and they were assumed to come from northwestern Greenland.

Turning to what Peary called the "glacial fringe" of north Ellesmere Island, we are on much less speculative ground. The first expedition to penetrate the Arctic Ocean by the Smith Sound route was that of Sir George Nares, in 1875–6, in the *Alert* and *Discovery*. The *Alert* wintered on the north coast of Ellesmere Island near Cape Sheridan and from this base Pelham Aldrich sledged west along the coast to Alert Point, over what is almost certainly the source region of the ice islands. He gives a very clear description of the ice, which he calls "ice waves" or "ice rollers".

"Several low ridges from 30 to 40 feet high, and varying from a few hundred yards to about a mile in length, show up in front of the cliffs. . . . I imagine these ridges are composed of hard ice under the snow, though I had no means of penetrating it any depth to find whether or no land lay underneath. . . .

"In passing between the island [Ward Hunt] and the main land, we crossed a ridge about 30 feet high, and ½ a mile in width, which runs quite a mile from about the middle of the south shore of the former. Thinking it was land, I dug down through 2½ feet of snow, and came to ice. Similar looking ridges extend to the eastward and westward of the island." (Parliamentary Paper, 1877, p. 201-2).

"I cannot make out where the land ends and the ice begins. . . There is no crack, but the shelving land appears to blend with the ice, which rises in the form of a roller, with a second roller behind it, exactly as water rolls on a beach after a breeze of wind." (p. 203).

"After lunch we sounded, and came to solid ice, under 4½ feet of snow, but from the height and extent of the ridges, I should imagine land lay beneath." (p. 213).

He mentions these rollers particularly at Disraeli Bay, M'Clintock Bay, Yelverton Bay, and around Cape Alexandra.

Peary, who is the only other man to lead a sledge party over this ice, is equally exact in his description of it. He travelled the whole length of the north coast and first mentions the wavy ice west of Point Moss, which is roughly the eastern limit of it today. ". . . we encountered for the first time, what later became a constant and striking feature of the glacial fringe, the long, prairie-like swells of its surface. . . The swells which we traversed coming from Point Moss, showed up beautifully from here [high land near Cape Columbia] as parallel swells following the main contour of the shore." (Peary, 1907, p. 181). Again, at Cape Alexandra he describes "the series of rolling swells which are a feature of this peculiar ice-foot (?)[1]. . . These swells are on a large scale, and reminded me very strongly of portions of the ice-cap of Greenland. If they are not huge drifts, I do not know how to account for them." (p. 185).

[1]The question mark is Peary's.

Photo: R.C.A.F.

Fig. 20. Yelverton Bay, north Ellesmere Island, 15 July 1950. Very little of the shelf ice remains in this bay. Note the ice island near the edge of the fast ice at upper left.

On the return journey, in the second half of July, again near Cape Columbia, he says: "Coming back over the bluffs, to our camp the orography of the glacial fringe both east and west was very strongly brought out by the streams and blue lakes which filled every depression and furrow. I took some photos, but was not sanguine as to their success." (p. 231). Apparently he was justified in his lack of sanguinity, because the photos unfortunately do not appear in his book.

Two very interesting points are brought out by comparing these accounts of Aldrich and Peary with the air photographs. Aldrich describes the "rollers" in Disraeli Bay as running approximately SE.–NW., and states that therefore on the east side of the bay they were more or less at right angles to the coast and on the west roughly parallel to it. Peary, speaking of the same area, says "Off Ward Hunt Island and especially the western end, they [the ridges] are particularly marked, and here they blend into drifts formed in the lee of the island." (p. 185). Both these observations are quite strikingly borne out by

the air photographs (Fig. 1), showing that this ice has very likely not moved in the last seventy-six years.

In Yelverton Bay, on the other hand, both travellers give the impression that it too was full of rollers, whereas today this is not the case. "Looking back on to the bay [Yelverton], I observed a series of ice rollers, two of which we crossed over yesterday." (Aldrich *in* Parliamentary Paper, 1877, p. 213). "The glacial fringe here has a distinct glacier characteristic in that its surface is undulating, and there is a gradual descent in going away from the land." (Peary, 1907, p. 189).

Peary, who is the only man to have gone beyond Yelverton Bay, describes a similar undulating surface all the way round the coast: "The edge of the ice was still visible [beyond Cape Alfred Ernest], but it was because we were up above sea-level on the undulating surface of the glacial fringe." (p. 190). "The surface of the glacial fringe during this march was intersected with narrow water cracks which seemed to delimit the larger swells, and I observed some hummocks and true crevasses." (p. 191). "The ice traversed in this march was a succession of swells of moderate height. The light and shade after the sun came out, allowed the undulations of this remarkable ice-foot to be very clearly seen, and I was more and more reminded of the ice cap." (p. 201). "I then headed directly across the strait [Nansen Sound] to the northern extremity of the western land [Axel Heiberg Island]. The ice in the Strait was to all appearance a continuation of that forming the glacial fringe of the Grant Land coast." (p. 203).

From these extracts it is quite clear that the "glacial fringe" extended all along the coast and even into Nansen Sound, though it seems more probable that the "continuation" he speaks of may have been a detached portion—in fact an ice island. In any case, the photographs today show only a few broken pieces and a small remnant of fast ice in Yelverton Bay (Fig. 20), and unconnected patches to the west of it. It would appear therefore that there has been a great deal of breaking out of this ice since 1906. These facts, together with the undoubted recession of many of the glaciers on this coast since Peary's time, seem to support the theory that the shelf ice is a relic formation.

Lockwood, of Greely's expedition, makes one or two references to "undulating ice" on the north coast of Greenland, which he followed from Robeson Channel to Cape Washington, but gives no clear description of it (Greely, 1886). It would be interesting to see air photographs of this coast. Koch's photographs taken in 1938 (1940) show only the upper reaches of the fiords, and no undulations are apparent.

It will be seen from these extracts, the result of a fairly extensive but by no means exhaustive study of the literature, that it is at least likely that travellers in the Arctic Ocean and among the Canadian Archipelago have met with ice islands in the past, and that the shelf ice of the north coast of Ellesmere Island has retained its major characteristics over a period of at least seventy-six years. No very definite conclusions can be drawn from these observations as there can

be no proof that even the most likely examples were actually ice islands. It is however of some interest to consider the areas involved and compare them with the distribution of ice islands in recent years as shown on Fig. 10.

The most likely descriptions come from three areas. The first is the Arctic Ocean somewhere to the north of Axel Heiberg Island (Cook). This is the general area of the drifts of the three Ts. The second is the Beaufort Sea (Storkerson and Takpuk's island), and is near but well to the south of an area where T1 has been sighted and where T3 may be assumed to have passed. The third area is from Robeson Channel to Smith Sound (Greely). In this area more possible examples have been found than anywhere else, yet a search of the photographs has revealed no ice islands. The photographic coverage is incomplete but it is possible to say with some conviction that there were none on the Canadian side at the time of photographing. This may be coincidental, but it is also possible that in the middle of the last century the shelf ice extended farther east than it does now, just as in Peary's time it extended farther west. Islands from this eastern extension might well have found their outlet through Robeson Channel, and the source being now more or less exhausted they would no longer be so likely to occur in this area.

The other parts of the Canadian Archipelago where possible ice islands were found—Eureka Sound, Isachsen Peninsula, Emerald Island—are all areas where they have been photographed recently. Of the instances off the Siberian coast it is impossible to speak as so little is known, but it seems reasonable to suppose that some islands might escape the northerly current that is presumably responsible for the course of the three Ts from Alaska to the pole, and travel across to the area of the drifts of the *Jeannette*, *Fram*, and *Karluk*.

Part IV. Comments on the Origin of the Ice Islands. *By Geoffrey Hattersley-Smith*[1]

The great area, thickness, and structural strength of the ice islands, as well as their rolling relief, distinguish them from other forms of ice encountered in the polar sea, and suggest that they originated neither as sea ice, nor by calving from the snouts of valley glaciers. When detailed information on the ice of these islands is available from the work of the U.S. party, who are spending the summer on the island T3, we shall be able to make more definite deductions about the ice of their source area. Preliminary reports mention that seismic soundings have given an average ice thickness of 200 feet, with a maximum thickness of about 250 feet, and a maximum height above sea level of 40 feet. The crests of the "rolls" which characterize the surface are 300 to 1,000 yards apart and about 10 feet in height. In some places the "coast" falls away in a smooth slope to the pack ice; in others there are cliffs up to 30 feet high. Rafted pack ice, standing on edge, flanks some parts of the coast and testifies to the great pressure of the pack, against which the island has maintained its shape for at least the last six years.

[1]Arctic Section, Defence Research Board, Canada.

The air photographs of the northern Ellesmere Island coast show that ice formations resembling T3 fill many of the fiords and fringe the coast between them. This ice is continuous between Cape Columbia and Yelverton Bay, with isolated patches to the east and west. This "glacial fringe", the presumed source of the islands, appears to have the characteristics of shelf ice as known from the Antarctic. It connects the ice of the fiords and grows out from the coast for up to about 10 miles, and is presumably afloat for much of this distance. Consideration of the origin of the ice islands therefore resolves into a consideration of how the shelf ice has developed and what is causing it to break up. It is very desirable that this ice should be studied by a glaciologist on the ground; in the absence of definite knowledge the following comments are naturally speculative.

The idea of shelf ice occurring in the Arctic may be unfamiliar, but it is by no means new. Thus Greely (1886, Vol. 2, p. 47) was in no doubt that his "palæocrystic floebergs" originated from ice of the barrier or shelf type, though Nares considered they were old hummocked sea ice. Recently Wordie (1950, p. 416) has drawn attention to the coloured illustration of a "floeberg" in 'Shores of the Polar Sea' (Moss, 1878, Plate 12) as indicating the existence of shelf ice formations. This floeberg, although stratified like the antarctic shelf ice, is described by Moss, one of the doctors on Nares's expedition, as "of salt ice".[1]

Glacial conditions in north Ellesmere Island

The great glaciers at the heads of the large fiords along the north Ellesmere coast draw their supply from the Highland Ice[2] of the mountainous interior. The amounts of snowfall and wasting in this inland region, where the mountains rise to 10,000 feet, are not known. However, it seems likely that the annual snowfall is appreciably greater than the average of 2 inches of water recorded at Alert on the northeastern Ellesmere coast, though scarcely enough to maintain the icefields at their present size.

Near the coast there are very obvious signs of glacial recession. Glaciers have receded from the rock walls of their valleys, tributary glaciers have shrunk back from their former junctions with main glaciers and in some cases have been cut off from their parent snowfields (Fig. 1). It is safe therefore to conclude that the main glaciers, which reach the coast, must be tapping reservoirs of ice accumulated in a period of greater snowfall. The retreat of the smaller tributary glaciers must have caused considerable thinning of the shelf ice in the fiords in recent times, and hence must have contributed to its tendency to break up. The recession apparent in northern Ellesmere is also evident in other parts of the island. In the southwest Schei (*in* Sverdrup, 1904, p. 465) writes of "thin ice-mantles and stationary snow-fields, which are unable even to feed the valley glaciers." According to Bentham (1941, p. 44) most of the glaciers in the southeast appear to be stationary or retreating a little.

[1]Moss noted that some of the larger palæocrystic floebergs "could not be less than two hundred feet deep" (1878, p. 29).

[2]The ice is not thick enough to conceal the underlying topography (see Wright and Priestley, 1922, p. 148).

During the maximum extension of the glaciers and shelf ice of northern Ellesmere it may be supposed that the lower parts of the hilly peninsulas between the fiords were covered by ice, and that this ice continued out to sea and formed a continuous shelf with the ice from the fiords. With the gradual withdrawal of the ice from these peninsulas the outlying parts of the shelf were in many places severed from the glaciers. Emergence of the land, possibly through isostatic recovery, must have had a considerable effect on the coastline and on the course of deglaciation in the immediate coastal region; de Rance and Feilden (*in* Nares, 1878, Vol. 2, pp. 341-2) have shown that the north Ellesmere coast has risen by some 300 feet in recent times. This emergence must have been a factor in determining on which parts of the coast the shelf ice could maintain its hold as conditions became more unfavourable. Recent increases in temperature and salinity of sea water, for which there is evidence from other regions of the Arctic (Ahlmann, 1949, pp. 186-7), may have been most destructive to the ice shelf.

Deglaciation in the coastal region of northern Ellesmere has probably taken place very much on the lines suggested by Flint (1929). With the stagnation of the glaciers and icefields, which accompanies deglaciation, wasting becomes controlled mainly by the topography. As soon as rock surfaces or nunataks make their appearance, the rate of melting of the surrounding ice is greatly accelerated; this is especially noticeable where the rocks are of sedimentary origin—as in northern Ellesmere—rather than of igneous or metamorphic origin. Along the nearby coast of north Greenland, Lauge Koch (*in* Rasmussen, 1921, pp. 310-1) has commented on the rapidity with which the snow disappears in the mountains in comparison with its rate of disappearance at sea level, especially on the sea ice. Doubtless this is in part due to the wind blowing the snow away to low sheltered areas, but Koch implies that it is also due to the very marked rise in air temperature with height above sea level which in turn is related to the insolation at exposed rock surfaces. The shadows cast by the high mountains, the low altitude of the sun, and the northern aspect of these coasts would also assist in preserving the lowland ice.

There is a further factor which favours the persistence of lowland ice—especially shore-fast ice. According to Flint (1929, pp. 259-60), "The difference in rate of disappearance between highland ice and lowland ice is increasingly accentuated by the fact that the meltwater that escapes from the vanishing highland ice necessarily washes the entire débris content of the ice, plus much of the surface débris of the newly exposed highlands, down on to the surface of the lowland ice, where much of it remains as an insulating blanket, sheeting over the glacier remains and materially retarding their rate of melting. Vegetation may gain an extensive foothold on this . . . waste." This blanketing of the ice has certainly taken place along the northern coast of Ellesmere Island. Near shore at Cape Colan late in April Aldrich (*in* Nares, 1878, Vol. 2, p. 12) found beneath the snow "a thin layer or covering of soil or mud lying on top of the hard ice." Nares makes the comment that this discovery was to be expected from the amount of soil and gravel which he saw deposited on the ice by the summer torrents later in the season.

Outwash and morainic material are therefore to be expected on ice islands which have broken away from that part of the ice shelf nearest to the shore. The U.S. party have found morainic boulders on T3, and Eric Fry's photographs of the ice island near Stor Island in Eureka Sound in 1950 show large amounts of outwash and morainic deposits 40 to 50 feet high (Fig. 16).

Glacial regime on the ice shelf

There is very little information on nourishment and wasting on the ice shelf itself from the records of Nares's and Peary's journeys along the north Ellesmere coast. In spite of the low precipitation large depths of drift snow were encountered. Nares (Parliamentary Paper, 1877, p. 19) reports that only 6 to 8 inches of snow fell during the winter, yet in the following months of April and May Aldrich (*in* Nares, 1878, Vol. 2, p. 12) found depths of from 1 to 4½ feet of snow resting on a thin layer of soil or mud above hard ice near Cape Colan. The U.S. party on T3 also reports finding snow resting on a few inches of dirty, porous ice which may contain volcanic ash and cosmic dust; immediately below the dirty ice there is clear glacier ice. In neither of these records is there any mention of firn or "snow-ice".

On the assumption that T3 has broken away from the shelf ice of northern Ellesmere Island, it would seem that during recent decades at least no increment to the surface of the shelf ice has been taking place by firn formation, except possibly in a few places close to the shore where unusually large amounts of drift snow may accumulate. Peary records that on 15 July 1906 most of the snow had melted on the shelf ice of Disraeli Bay (1907, p. 228). There is still the possibility of a small annual increment through refreezing of meltwater at the surface of the ice, as occurs on the Barnes Icecap (Baird, 1952). Summer meltwater naturally tends to concentrate in the troughs of the rolls, as is shown in the air photographs and as Peary (1907, p. 231) has recorded. If refreezing greatly exceeded wasting the rolls would in time become levelled off unless the forces which produced the rolls are still acting. The writer suggests that the rolls for the most part reflect actual folding of the ice due to pressures which, in some parts of the ice shelf, have acted in the past but which are no longer acting (see pp. 100–1). If this is so, it would mean that present summer wasting at the surface of the ice shelf from whatever cause is equal to or exceeds the annual accumulation.

It is unlikely that any increment is now taking place at the under-surface of the ice shelf because of the high temperatures caused by the large amounts of summer meltwater from the land which drain down beneath the ice. Thus Markham (*in* Nares, 1878, Vol. 2, pp. 64-5) reports a temperature of 31.8°F at a depth of 9 feet and 29.0°F between 12 feet and the bottom in 12 fathoms; he concludes that "The very marked change . . . [in temperature] between the water at a depth of nine and that at twelve feet is evidently due to the meeting of the freshwater running off the melting ice and the sea water." Moss (*in* Nares, 1878, Vol. 2, pp. 61) expressed the opinion that "waste exceeds growth near shores."

Formation of the shelf ice

Off the north Ellesmere coast it is probable that both the normal processes by which a sheet of shelf ice may be formed have been important. These are:

1. By the floating ice tongues of separate glaciers pushing out to sea and coalescing. (Sea ice may form in the interstices and become incorporated in the main mass. However, "the characteristics of Shelf-Ice . . do not appear until the contours of the original glacier ice and sea ice have been swamped beneath a heavy accumulation of snow." (Wright and Priestley, 1922, p. 164)).
2. By the accumulation of snow upon sea ice which has persisted for several seasons.

In the inner parts of the fiords, where the ice appears to be very thick, the main glaciers and their tributary glaciers seem to have been the chief sources of supply; in the outer parts of the fiords and along the coast between the fiords the shelf ice seems to have grown mainly through the accumulation of snow on sea ice. Lauge Koch (1923, p. 54-5) in his classification of the glaciers of northwestern Greenland describes the ice conditions in certain fiords, and it may well be that the shelf ice along the north Ellesmere coast originated in much the same way. "On account of the climatic conditions at the inner end of deep fjords, the sea ice as well as the projecting tongue of the glacier increase in height, the annual precipitation finding no outlet. For this reason no line of demarcation can be drawn between the sea ice and the glacier. The sea ice in the fjord moves with the glacier almost as far as to the mouth of the fjord, forms fissures, and pushes moraines over projecting headlands or islands in the fjord." In north Greenland this old fiord ice is referred to as "floating inland-ice", and Koch (*in* Rasmussen, 1921, p. 331) adds that: "The Eskimos call it 'Sikussaq'—*i.e.*, ice which resembles the ocean-ice."

Calving from the shelf ice

Calving from an ice shelf is at its greatest either at the maximum glaciation when the shelf is pushing actively forward, or when the supply is cut off and the shelf is slowly disintegrating *in situ*. There is no information on the rate of movement of the Ellesmere shelf ice in the fiords, nor on the proportion which is afloat. In view of the low snowfall and the general recession of the tributary glaciers, the guess may be hazarded that in most of the fiords the forward movement of the main glaciers is largely dissipated before the sea is reached. The seaward movement of the shelf ice near the mouths of the fiords is probably very small indeed. Those parts of the shelf which form a coastal fringe between fiords presumably can have no outward movement at all; their periodic calvings to form ice islands show that their present hold on the coast is precarious. They may well be relic portions of a former more extensive sheet of shelf ice along this coast.

"Relic glacial forms" of probably similar origin on the west coast of Graham Land in the Antarctic have been described by Fleming (1940), who concludes that: "The island ice-caps and the fringing glaciers . . . are unstable and ephemeral glacial features. The shelf-ice with which they formed a continuous sheet and to which they owed their development must have broken away from the coast quite recently." (p. 100).

It is possible that the fringe of shelf ice on the north coast of Ellesmere Island is only able to maintain its present hold through the presence of small off-shore islands, which it has swamped and to which it is firmly anchored. In some of the air photographs small islands can actually be seen in the process of emerging through the shelf ice. In the Antarctic small off-shore islands and shoals are thought to be important factors in the development and maintenance of the Larsen Ice Shelf, east Graham Land (Reece, 1951, p. 408; Mason, 1951, p. 514), and of the Shackleton Ice Shelf, King George V Land (Mawson, 1942, p. 324).

Wind action, tide action, and pressure from the pack may cause cracks to develop in the ice shelf, and so hasten the ultimate calving of ice islands. With the presumed increase in the temperature of the polar sea in recent times these cracks may remain open longer. Near the shore meltwater streams cause decay of the shelf ice, thus hastening disintegration in which wedge-shaped islands may be produced. T2 and T3 each have one end markedly higher than the other which suggests that they may have come from a shore-fast part of the shelf.

That the break-up of the Ellesmere shelf ice has been fairly rapid in recent years is suggested by Peary's description of the extent of this ice in Yelverton Bay in which only isolated fragments remain today (Peary, 1907, p. 189). It may be that the production of ice islands is now at a maximum.

Formation of the rolls

Rolls are characteristic of shelf ice in the Antarctic, and it is therefore not surprising that they occur in the Ellesmere ice shelf. The rolls may be due to a number of causes: these include movement of the glaciers, movement of the shelf ice, pressure of the pack ice, temperature changes, tidal action, and wind action.

The rolls in the inner parts of the large fiords must be regarded as pressure ridges caused by the seaward movement of the main glaciers, modified by lateral pressures exerted by tributary glaciers. This force could scarcely be affecting the outer parts of the fiords today where movement of the shelf is either very small or non-existent.

In certain small bays and inlets it is difficult to explain forces of sufficient strength to produce rolls in ice of such evident thickness. The rolls may therefore result from the weathering of ice folded at an earlier date through glacier or shelf ice movement. Stratified ice contains layers of various hardnesses and porosities, and it may be expected that weathering, as in sedimentary rock, will bring out secondary structures in folded ice. If this is in fact occurring it would seem to support the view that the present state of the ice shelf is one of surface waste and not of growth. On the other hand, on a portion of the ice shelf which has broken away to form an ice island, it may be that growth will occur by refreezing of meltwater or firn formation as the islands drift to a colder region or one of higher precipitation. Miller (quoted on p. 73) suggests that this may partly account for the smoothing out of the rolls on the ice islands T1 and T2. Those islands which drift to a

warmer region will naturally weather through increased melting, which would also cause smoothing out of the rolls.

In the outer parts of the fiords and along the exposed parts of the coast between fiords the rolls are generally parallel to the coast. It may be that here their persistence and origin are largely due to the great pressure of the pack ice on the edge of the shelf. A bay to the west of Phillips Bay shows a system of low, closely spaced rolls in the outer part of bay-fast ice of moderate thickness. A little way back from the mouth of the bay the ice is smooth, showing that these rolls are recent and due to pressure of the pack. Although this ice may persist long enough to be called semi-permanent fast ice, it is unlikely under present conditions that it can reach sufficient thickness to justify being called shelf ice. It does, however, point to the possibility that the outer parts of the northern Ellesmere shelf ice may have been formed from semi-permanent fast ice.

Rolls may also be partly due to pressure induced by temperature changes, which would also account for their parallelism to the shore. Wright and Priestley (1922, p. 344) give this explanation for ridges and troughs parallel to the shore in bays on the east side of McMurdo Sound in the Antarctic: "a rise of temperature, acting over a very large area, causes expansion in the ice-sheet, especially when the latter is thick. This, in its turn, sets up considerable pressure which is usually concentrated along shorelines, or against immovable objects such as islands and stranded bergs."

In the Antarctic tidal action has also been suggested as a possible cause of parallel rolls near the seaward edge of shelf ice, notably on the Ross Barrier (Poulter, 1947, pp. 377–9 and 382–3; Debenham, 1949, pp. 210–1). These features are attributed to fracture throughout the depth of the ice caused by the rise and fall of the tide on the seaward side of a portion of the barrier which is grounded on moraine. The fractures become filled with frozen sea water from below and with drift snow from above (see Siple, 1945, Fig. 38, p. 57). The tidal range off the northern Ellesmere coast is small, but it is also small in the Ross Sea area. Therefore, in the present state of knowledge tidal action as a possible cause of rolls should not be discounted, although in the Arctic the effect of the tide is greatly reduced by the density and persistence of the pack ice, even in summer.

Wind action is unlikely to be the main cause of rolls, although it may influence their development. In general wind-driven snow would be expected to fill up the troughs between rolls and so obliterate them. That this does not seem to happen is another reason for believing that summer wasting exceeds the preceding winter's snowfall.

In the light of all the known facts it is difficult to reconcile the development of an ice sheet of considerable thickness with present conditions along the northern Ellesmere coast. The development probably took place before the post-glacial climatic optimum in a period of greater precipitation, lower summer temperatures, and lower sea temperatures. Accumulation of drift snow at the foot of the coastal mountains may have been a more important

factor than at present, and may have influenced the growth of the shelf ice, as has been suggested for the Larsen Ice Shelf in the Antarctic (Mason, 1951, pp. 513-4). In the outer parts of the fiords and along the coast between the fiords the ice shelf should be regarded as a relic glacial feature. It is the periodic breaking-off of large areas of this shelf which has formed the ice islands at present drifting in the Arctic Ocean and channels of the Canadian Archipelago.

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*Consulted in translation only.

Fig. 1. Cape Searle.

Photo by V. C. Wynne-Edwards

THE FULMARS OF CAPE SEARLE

V. C. Wynne-Edwards*

In July 1937 I met Dr. L. D. Livingstone, who was returning as medical officer to Pangnirtung, on board the *Nascopie*, and it was he who first told me of the great fulmar colony at Cape Searle (67°13N., 62°30W.), on the Davis Strait coast of Baffin Island. That summer I joined Commander Donald MacMillan's expedition at Hebron, and paid a visit to Frobisher Bay in the Gloucester schooner *Gertrude Thebaud*. Though we cruised the open waters of Davis Strait north to about 66 degrees, we had no contact with the coast and learnt nothing further about fulmar nesting sites.

There appear to be four colonies known at the present time in eastern North America, all of great size. There is one at Cape Searle; another, also seen by Dr. Livingstone[1] about 1 June 1927, on the 1,500-foot cliffs at the mouth of Coutts Inlet, farther north on the east coast of Baffin Island; one found by Peter Freuchen in northwest Baffin Island in 1924, between Elwin Inlet and Baillarge Bay on the eastern shore of Admiralty Inlet, where it opens out into Lancaster Sound (Hørring, 1937, p. 43); and finally the "big breeding colony" discovered by O. Sverdrup at Cape Vera, Archer Peninsula, Devon Island on 8 August 1900 (Schaanning, 1933, p. 162). There are quite possibly other colonies as yet undiscovered. Mr. G. W. Rowley[2] reports that fulmars appeared to be breeding in cliffs in Adams Sound, farther south in Admiralty Inlet, in 1937.

References to Baffin Island fulmar colonies are exceedingly few and meagre. Ludwig Kumlien (1879, p. 101–2), naturalist of the Howgate Polar Expedition, first suggested the existence of a colony near Cape Searle. He records also that in July 1878 he found a few breeding near Quickstep Harbour in Cumberland Sound, on some small rocky islands. Quickstep Harbour is on the north side of Cumberland Sound about 16 miles northwest of the entrance to Pangnirtung Fiord, that is, near the head of the sound and more than a hundred miles from the open sea of Davis Strait. This is a most improbable place. In the Baffin Bay region, including west Greenland, small fulmar colonies of a few pairs are almost unknown (cf. Salomonsen, 1950b, p. 32), and the sites chosen are generally majestic cliffs, overlooking or close to open water of relatively high salinity, and not in such a landlocked sea as the upper part of Cumberland Sound. Kumlien's 'Contributions to the natural history of Arctic America' are exceedingly valuable, but they are not entirely free from major errors of this sort; and since more recent observation shows that

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[1]Note in the records of the National Museum of Canada.

[2]Oral communication.

fulmars are never at all numerous in Cumberland Sound (Soper, 1928, p. 86), my own opinion is that until further evidence is forthcoming the Quickstep Harbour record should not be accepted.

After mentioning the fulmar colony which he saw at Blåfjaeld (Mt. Uivfak, west Greenland, Kumlien continues with the following paragraph, which is quoted in its entirety.

"In Exeter Sound and to the northward along the west shores of Davis Straits and Baffin's Bay, the dark variety seems to predominate. Near Cape Searle they are extraordinarily abundant, breeding by thousands on the Padlie Island, and they are so tame about their nesting-places that they can be killed with a stick. The eggs, even after being blown, for many months still retain the musky odor peculiar to the birds. Perfectly fresh eggs are quite good eating, but if a couple of days old the musky odor has so permeated them, even the albumen, that they are a little too much for a civilized palate."

This is a puzzling statement. In the last part he evidently refers to his own personal experience of eating fulmars' eggs; but at Cape Searle at the present day no one would think of describing the birds on the inaccessible towers as tame, nor for a moment of trying to reach them with a stick. This discrepancy is emphasized by his omitting to give any hint that Cape Searle presents an extraordinary and unforgettable sight: the possibility indeed suggests itself that there may be some mistake or confusion.

The Editor has very kindly drawn my attention to Kumlien's reference (p. 105) to the largest rookery of Brünnich's murres he found, "being on the Padlie Islands in Exeter Sound"; and, further, to information received from the Eskimo by Mr. T. A. Harwood in 1938, that fulmars breed on Kaxodluin Island,[1] a low-lying island with a steep cliff, near the entrance of Exeter Sound, where it would be quite possible to kill the birds with a stick. These are either the same or neighbouring islands; and to me the most probable solution is that Kumlien's account refers wholly to the latter fulmar colony in Exeter Sound, which is not otherwise mentioned. The not unreasonable assumptions must be made either that he failed to identify correctly the Cape Searle of Ross, or that some confusion arose between the different "Padlie Islands". This at least provides an explanation for the two curious facts, first that he mentions one and not both 'Padlie Island' colonies, though we know he visited Exeter Sound; and second, that the description given contains no reference to the commanding site on Cape Searle, and seems wholly inappropriate to it.

Cape Searle was well known to the Scottish whalers, and in 1860 the ship's surgeon James Taylor made a collection of plants there, and published them in a list of plants and ferns collected on both sides of Davis Strait and Baffin Bay (1863), though he left no narrative or description of the cape.

The only other early records of fulmar colonies known to me are those of Franz Boas (1885), the ethnographer, whose journeys in Baffin Island in 1883–4 excite the keenest admiration. Boas was particularly active in collecting

[1]This name is given in the 'Sailing directions for Baffin Bay and Davis Strait' (1947, U.S.H.O. Pub. No. 76), but has not been officially adopted by the Canadian Board on Geographical Names.

Fig. 2.

Eskimo place names, and his maps show no less than five places called 'Kaχodluin' (= Qaqudluk = Oohudluk), meaning fulmar, besides two others using this word with added terminations. In one of the latter, namely 'Kaχodlualung' in

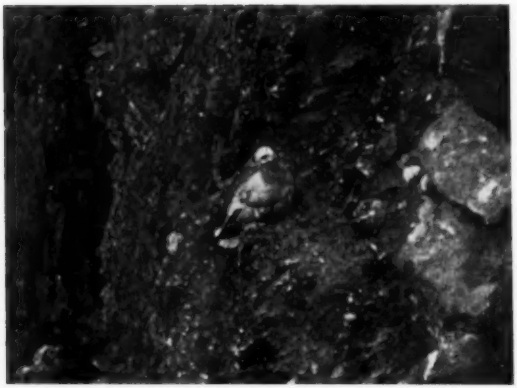

Fig. 3. Cape Searle is not a suitable place for photographing fulmars at the nest because of their inaccessibility. This bird is an 'intermediate' in plumage.

Clearwater Fiord at the very head of Cumberland Sound, the unexpected sight of a fulmar, or perhaps a shearwater, could have been the occasion of giving the name, since it is a place where fulmars are unlikely ever to be particularly numerous.

One *Kaxodluin*[1] is the island of which Cape Searle is the northeastern point which Boas passed a day or two after 22 May 1884, on a sledge journey north to Kivitoo; a second is evidently Freuchen's site on Admiralty Inlet. There remain three others, all perfectly possible sites of fulmar colonies, namely Kaxodluin Island, 22 miles ESE. of Blacklead Island, near the mouth of Cumberland Sound (visited by Boas in early March 1884); Leopold Island off Cape Mercy; and Kaxodluin Island in Exeter Sound (66°15N., 62°15W.). There is a keen incentive to follow up these tantalizing clues, and explore the 150-mile stretch of capes and outer islands between Cumberland Sound and Cape Dyer, as yet unvisited by a naturalist.

One other interesting item is to be found in Boas, whose references to the fulmar are unfortunately confined to place-lists in the appendix. He suggests (p. 94, footnote) that Cape Searle is perhaps the Sanderson's Tower of John Davis. (William Sanderson was the principal patron of Davis's three voyages in search of the Northwest Passage). Sanderson's Tower appears, not in the log, but only as a name inserted on the famous 'New Map of the World' of 1600,[2] lying north of Mount Raleigh (Exeter Sound) in the general region of Cape Searle; but the map is so small and inaccurate that certain identification can never now be made. Davis may have named Sanderson's Tower on the First Voyage in 1585, but more probably on the Third in 1587. Certainly Ross was mistaken in identifying the name with what is now called Leopold Island, much farther south, although the latter is 2,000 feet high and according to Ross (1819, p. 219) "resembled a martello tower". As has been said, it was Ross who named Cape Searle (1819, p. 209).

[1]Boas uses the Greek χ usually transliterated *kh* or *ch*, but the letter *x* has been given here because 'Kaxodluin' is the officially adopted Canadian name for the island in Cumberland Sound; the U.S. 'Sailing Directions' also refers to the island in Exeter Sound as 'Kaxodluin'.

[2]Hakluyt Society, 1880. Published to illustrate the voyages of John Davis.

After Kumlien and Boas there was no news of Cape Searle until Dr. Livingstone's visit in recent times. It is in fact extraordinary how little has been generally known about the fulmar's nesting colonies in Arctic America, considering its abundance in the region. When Mr. P. D. Baird invited me to join his 1950 expedition to Baffin Island[1] I made known to him my long-standing wish to go to Cape Searle; and though it was a very long way from our base at Clyde, he at once consented to include it among the objectives of the expedition.

The races and distribution of the fulmar

Before describing our visit, it is necessary to say a few words about the fulmar itself. It is of course a petrel, related to the albatrosses and shearwaters, and like them a deep-water bird. It is nearly circumpolar in distribution, and remarkable for the fact that the colour varies between a 'light phase', with white head and underparts and grey wings, not unlike a gull, and a 'dark phase', in which the whole of the plumage is a dark smoky grey. There is a complete range of intermediates, and the proportions in which light and darker birds are mixed together varies tremendously from one part of the range to another. The colour differences are independent of age or sex. The span of the fulmar's wings (one measured 42 ins.) is a few inches longer than that of the kittiwake, but much less than that of a herring gull (about 56 ins.).

There are three geographical races at present recognized, namely one in the North Pacific and two in the North Atlantic. The Pacific fulmar, *Fulmarus glacialis rodgersii*, though variable, is quite distinct. The two named Atlantic types, *F. gl. glacialis* and *F. gl. minor*, however, appear to form part of a cline or graded series, though details of the situation are not yet fully worked out.

In all races the males and females differ somewhat in the size of the bill, that of the male being both stronger and longer than that of the female. This sexual dimorphism is least marked in *rodgersii*, in which even the male has an effeminate bill with a weak 'nail', by no means so robust as that found in any of the Atlantic series (Fig. 4).

The length and strength of the bill also varies geographically, and is the basis upon which the various races may most readily be distinguished. The largest bills are to be found in the fulmars of the British Isles, Faeroes(Færøerne), and Iceland. Breeding birds from Spitsbergen (the type locality of *F. gl. glacialis*, as designated by G. M. Mathews, 1934), Bear Island (Bjørnøya), and Jan Mayen (and probably Greenland) have rather smaller bills, and form a group with a mean bill length significantly different from that of either the previous group, or of those breeding in Baffin Island. The latter have the smallest bills of all, and have lately been recognized by Salomonsen (1950a and b; see also "Twenty-sixth supplement to A.O.U. Check-list", *The Auk*, Vol. 68 (1951) p. 367) as the short-billed fulmar, *F. gl. minor*.

Besides the bill, there are other variable characters. Though the wing-lengths of all fulmars fall within much the same rather wide range, there is little doubt that the Icelandic–British type is on the average a substantially

[1]Supported by the Arctic Institute with funds provided through the U.S. Government.

heavier bird than that from Cape Searle. Incidentally, the males, in all Atlantic populations at least, average heavier than the females, and, as Salomonsen showed, birds with big bill's have big skulls and heads and *vice versa*.

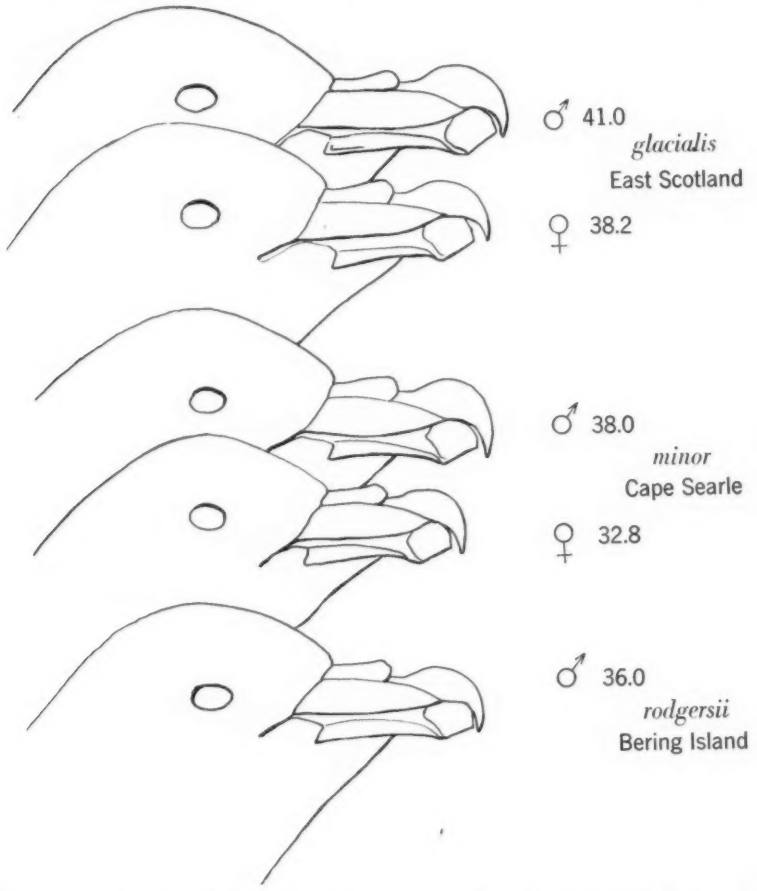

Fig. 4. A comparison of the bills of the three races of *Fulmarus glacialis*. (X 2/3). The figures show culmen-length in mm. of these individual birds, but are near average for the subspecies and sex concerned. Note the greater strength and curvature of the 'nail' in the males of *glacialis* and *minor*, and the 'female' appearance of that of the male *rodgersii*.

In the Icelandic–British group, birds not in the typical light phase are decidedly rare, no doubt less than one in a thousand; and the greyest birds which do occur are not as dark as the darkest found in Baffin Island. The latter are in turn slightly surpassed by the darkest *rodgersii*. At Cape Searle, as described below, only about one bird in eight is of the typical light phase, and about the same proportion are extremely dark, the remaining 75 per cent

being intermediates. On the opposite side of Baffin Bay, on the other hand, in the Disko Bay (Disko Bugt) region of west Greenland, about 99 per cent of the breeding birds are in the light phase (Salomonsen, 1950b, p. 40). In northeast Greenland and Spitsbergen, "intermediate colour-phases constitute the main bulk of the population" (Salomonsen, 1950b, p. 40).

It will be noticed that there are two independent variables here, namely the proportion of white-headed birds, and the degree of maximum saturation to be found in the darkest individuals.

As a breeding bird in the Atlantic sector the fulmar generally avoids the continental mainland, and extends as a high-arctic bird from about 70°E. in Novaya Zemlya (possibly also Lonely Island (Ostrov Uyedineniya), 83°E.), and Franz Josef Land (Zemlya Frantsa-Iosifa), Bear Island, Spitsbergen, Jan Mayen, northeast and northwest Greenland, to Baffin Island. The known colonies, though often large, are not very numerous. The Icelandic–British group occupies a very different, temperate or boreal, environment, and has undergone a remarkable recent expansion of range, originating more than a century ago, and still continuing. In contrast to the ancient and metropolitan colonies, such as those at Cape Searle or St. Kilda, which seem elsewhere to be characteristic of fulmars, within the newly colonized region on the British coasts and isles there has been a rapid ribbon development of numbers of small or relatively small colonies, often situated on quite insignificant cliffs or bluffs. This tendency to pioneer and establish new colonies, instead of remaining to make the best of the old ones, may be something more than a mere consequence of the increase in numbers. It could, for example, be the primary result of an original mutation or hereditary change, which has brought about the increase in numbers and range in its train.

Whether wandering fulmars from the Atlantic sector occasionally mingle with those from the Pacific there is no evidence to determine. The latter are much more restricted in their range in the Arctic Ocean. Attention may be drawn again to the observation made in 1850, and the more recent specimen collected on 27 July 1916, at Banks Island in long. 125°W. (Rand, 1948, p. 175). This latter bird is now in the National Museum of Canada, and, though unsexed, has a bill-measurement normal for a female of the short-billed race (32.2 mm.); Rand was satisfied that it was not a *rodgersii*.

The bill-measurement (culmen from feathers) of a male collected by us at Cape Searle, 15 August 1950, is 38.0 mm.; of two females, 35.5 and 32.8 mm.; and of an unsexed skull 34.3 mm. These accord with the means of Freuchen's series from the Admiralty Inlet colony, namely, males 36.0 ± 0.4 mm. (standard deviation=1.7 mm.); females 33.1 ± 0.3 mm. (standard deviation=0.6 mm., which is probably too small; the number measured was only six).

Narrative of our visit to Cape Searle

The visit to Cape Searle in 1950 was left until after the middle of August, to make sure of open water conditions. The fulmars arrive early in the spring; they were already in possession of the cliffs in great numbers when Dr. Livingstone was there from 15 to 17 April 1929, though their nesting ledges were

still frozen and the ice no doubt extended far out into Davis Strait. The breeding season is about one month later than in the temperate climate of the British Isles; we were able to calculate from our observations that most of the eggs must have been laid just prior to June 15.

This late visit fitted in well with other plans, since by this time the biological work at Camp B, at the head of Clyde Inlet, was well advanced. There were five members of the expedition in the 'Padloping party': the pilot of the Norseman, Maurice King, who later lost his life on the Arctic Institute's Snow Cornice Expedition in 1951; Monty Ritchie, who had to be starting on his way south; and Mason Hale, Sandy Anderson, and myself. Maurice King fetched us from Camp B on August 12, and we spent a busy day at Clyde on the 13th preparing for the 350-mile flight to the southeast.

August 14: We tried to take off at 3.20 a.m., but there was an oily calm and the aircraft was too heavily loaded. Although we taxied out seven miles to the mouth of the inlet looking for a puff of wind, we made four or five runs without success, and returned to the post at 4.30. We tried again at 9.00, after pumping out 50 gallons of gas, but were still unsuccessful. Just as we came ashore again at 9.45 a strong breeze sprang up, and away we went.

As we passed low over the flat country of Cape Hewett, just south of Clyde Inlet, we saw a polar bear running, or loping, away, scared by the aircraft; and later three separate snowy owls. Over Home Bay we ran into fine weather, and could watch the changing panorama of magnificent mountains to the west of us all the way along the coast. We arrived at Padloping after a run of exactly three hours, and were met by the crew of the U.S.A.F. Meteorological Station with a carry-all and a truck to drive us up the bumpy road to the post. They were most hospitable, and gave us an enormous empty Quonset hut, with stove, beds, and table.

The seaplane which was to take Monty south was expected the following day, so he was extremely lucky. It got almost dark at night, and Jupiter was blazing in the low southern sky.

August 15: A very fine day. The PBY came in about 10.00 a.m. and left two hours later with Monty aboard. Very shortly afterwards Mason, Sandy, and I boarded a whaleboat with three Eskimo, and left at 1.05 p.m. for Cape Searle, sixteen miles to the northeast. Along the southeast coast of Padloping Island the high rugged cliffs of volcanic and sedimentary rocks were full of colour, a complete and not unwelcome change from the sombre gneiss of Clyde. We were in a wide channel, and at once among sea birds—dark fulmars, Brünnich's murres, black guillemots, and glaucous gulls. A group of harp seals in a small cove dived as we passed and did not reappear. About 4.00 p.m. we rounded the northeastern cape of Padloping Island, and immediately saw the majestic towers and jagged pinnacles of Cape Searle, three miles to the north.

Almost at once walrus were sighted, blowing like blackfish, and we gave chase. The Eskimo seized their rifles, and at first shot a bull was hit at 200 yards—a standing shot from the thwart of the pitching boat putting the bullet into his round back just at the water-line, as he broke the surface for a few

seconds. Then there followed a bloody chase. The herd, over a hundred animals, broke up, and several in our little group were badly wounded. The bull was killed, and, as we came alongside, the Eskimo thrust in a harpoon, and made it fast by the hide thong to a half-empty gas can (the sealskin bladder being stowed away and not at hand in the emergency of the moment). The calf swimming with him was shot also and hauled up over the gunwale with a short gaff. Meantime the bull sank, gas can, harpoon, and all, and was not seen again.

We went after another group, and another, and the water was red with blood. In the end we secured one bull of fair size, which was made fast alongside; but so rapidly do they sink that this, plus the small calf, was the total outcome of an hour's hunt, in which at the very least six walrus were mortally wounded.

We landed on Cape Searle island about 6.00 p.m. and put up the tent on the beach—the only level spot to be found. The Eskimo had a quick supper on their boat and proceeded to cut up the walrus into manageable pieces and pack it aboard, in all perhaps three-quarters of a ton of bone, meat, blubber, and hide. We were cooking and eating our own meal in the tent all this time. Shortly before 8.00 the skipper Anilik appeared and announced that they were going home. They assured us with much flourishing of wrist watches (of which they are excessively proud) that they would return tomorrow about 12. We should have to do the best we could without the boat, which, I confess, had appeared absolutely indispensable if we were to have a proper look at the cape.

The wind blew from the SW. at night, and there was some rain. We were lucky to have a sheltered spot, for we learnt afterwards that the Eskimo were obliged to seek shelter and lie up, and the gale at Padloping broke loose the huge pontoons used for a wharf, and drove them up on the beach.

August 16: Fair and calm, but mostly cloudy. We got up at 4.30 a.m. to make the best of the morning, and started for the bird cliffs at 6.00.

There is a six-knot tide-rip through the strait between where we camped and the Padloping shore opposite, running east on the flood and west on the ebb, with standing waves over a ledge running a mile out from our shore in the narrowest place. It was very popular with the fulmars, which floated in the stream by hundreds and fed, dipping their bills in the water. The walrus were there again also, far off.

The cape itself, where most of the fulmars nest, is totally inaccessible. The two huge towers, the bigger of which we called 'the keep' from its resemblance to a Gothic tower, are some 1,400 feet high and fall straight into the sea, so that there is access neither to the top nor the foot (except at sea level just at the inner end). We headed up the steep slope of the island, and found a way to the ridge top, 1,100 feet above sea level. The cliffs dropped away on every side, with fantastic pinnacles and buttresses, all orange-red with the bird-cliff lichen *Caloplaca elegans*; and everywhere the fulmars swarmed like flies. We were still 1,000 yards from the keep, but could see the cloud of birds over the summit, and away on either side far into the distance. The

Fig. 5. 'The keep', the inner tower of Cape Searle, from the nearest accessible point on the ridge, about 1,000 yards away. Photograph taken from a position 1,110 feet above sea level (by aneroid), and from here the height of the tower was estimated to be 1,400 feet.

summit was evidently covered with luxuriant vegetation, although so high and exposed, and there appeared to be an immense number of nesting birds right on the flat top. There were nests at all heights down almost to the cliff-foot, but they were everywhere much more numerous towards the top. Unfortunately the massive keep entirely concealed the outer tower of the cape from our view.

We could look into scores of nests relatively close at hand from our look-out. Each had a grey down-covered chick half to two-thirds grown (though in fact not more than about 15–20 days old, so fast is their initial growth). We saw a weasel (*Mustela arctica*) precariously hunting the uppermost ledges close below us, though there was clearly nothing left within its reach; these and the ravens, glaucous gulls, and white gyrfalcons probably take a considerable toll, though the main towers must be inaccessible to foxes or weasels.

I tried to estimate the probable population of the colony, and feel satisfied that it exceeds a lower limit of 200,000, though it may not be as high as half a million adult birds. An unknown proportion of the birds present were no doubt unmated or not breeding; and a figure for the number of birds in residence, including the immense numbers at sea within a 50-mile radius, has therefore more meaning than one for the number of breeding pairs. On our way home in the aircraft we made counts of fulmars flying over the water below, and could derive from these a rough estimate of their density of numbers. Naturally this rapidly diminished as the distance between us and Cape Searle increased.

Fig. 6. The towers of Cape Searle from the southeast.

The white-headed birds were much the most easily seen when sitting on the ledges, and there appeared to be about one of them in every five or six birds (23/126); but more careful counts made later at the tide-rip gave 44 light-phase in 373, or 12 per cent. The remainder were for the most part intermediate in shade, and only a similarly small proportion was really dark (some of them of a depth of grey seldom if ever found in the Atlantic sub-species).

As we walked back to camp along the beach it was 'blowing hot and cold', as it does on the Lower St. Lawrence, and the sea horizon was distorted. The Eskimo were not there, of course, nor did they come for over 24 hours.

In the afternoon there was some rain, and a strong cold north wind blowing banners of fog through the notches of the cape, and over the 3,000-foot mountains opposite on Padloping Island. At 1.45 p.m., when collecting fairy-shrimps (*Branchinecta paludosa*) from a pond on the beach with the butterfly net, I saw MacMillan's schooner *Bowdoin* pass south under fore- and stay-sail about two miles off the cape.

The morning's collection of plants included several good finds, such as *Tofieldia pusilla*, *Ranunculus sulphureus*, *Erigeron unalaschkensis* (a northern extension); also *Arabis alpina* and *Phyllodoce caerulea*, now for the first time confirmed in their northernmost known station, whence Taylor reported them in 1860; but I could not find his '*Gnaphalium sylvaticum*' (= *norvegicum*). (This is interesting, in view of Polunin's doubt (1940, p. 358) on the accuracy of Taylor's record of this plant, and his conclusion that it "needs confirmation"). I also obtained one specimen each of the butterflies *Colias hecla* and *Boloria freija*.

August 17: Bright, with a cold NE. wind. At 7.00 a.m. we tried to reach the foot of the keep along the shore and rocks; but it was high water, and there was a place where the heavy swell was breaking against the foot of an overhanging cliff. The morning was spent collecting and visiting the glaucous gull colony at the end of the sea cliffs nearest our camp, where over twenty pairs were breeding. Apart from some scattered black guillemots (*Cepphus grylle*) and the glaucous gulls, the fulmars are the only sea birds nesting on the cape.

Sandy skinned out the bodies of the birds we had obtained in the last two days, and we had an early dinner of fried breast of fulmar, murre, and guillemot: we all agreed that the fulmar was delicious and better than the rest.

At 12.00 we tried again, and had good fun running under the cliff from cove to cove between successive waves. We reached the green slope below the keep about 1.00 p.m. and had over half an hour there. It was extraordinary to look up the sheer walls hanging over 1,000 feet above our heads, with clouds of birds wheeling round them. The lush vegetation turned out to be chiefly mountain sorrel (*Oxyria digyna*) and the grasses *Trisetum spicatum* and *Alopecurus alpinus*. So rank was the growth that some of the sorrel leaves measured 9 cm. across. There was a well-used Eskimo camp-site on the flat, bare ground among the boulders at the foot of the cliffs, with an ugly accumulation of rusty tins and the wings and remains of many birds.

Soon after passing under the overhanging place on the way back we met Anilik coming to look for us. We reached the tent at 2.50 p.m., and were all packed and stowed aboard and on our way by 3.10. We found the boat all set for another walrus hunt, and an extra man along, evidently a crack marksman: but we saw no walrus, and only a small herd of harp seals, which vanished at the first shot.

It was a cold journey home of three-and-a-half hours, and the tarpaulin rigged over the fore part of the boat was welcome. To avoid the rough water out to sea we came round the north and west sides of Padloping Island, completing our circumnavigation of it; but the last two miles into Padloping were uncomfortably rough. The Met. boys gave us supper in the mess-hut with three eggs each and new bread, followed (after a suitable interval) by a hot shower and a comfortable bed.

August 18: Blustery weather. At 2.50 p.m. we took off for Clyde, on very rough water; while getting the mooring ropes aboard we drifted right among the rocks and only just got clear. Forty-five minutes after taking off we ran into fog patches, which soon got thicker and more continuous, extending from sea level to over 2,000 feet. It was not possible to make any radio contact, so we turned back to Padloping, landing about 4.30 on slightly calmer water. We learnt next day that farther north there had been heavy snow-storms all afternoon. It was a windy night, but the sky cleared and all the snow peaks to the south were lit up with rosy light at sunset.

August 19: Very fine, with a cold SW. wind reaching 35 m.p.h. We had a calm take-off, however, at 9.50 a.m., and flew along the north side of Padloping Island to Cape Searle, banking steeply round it close in to the cliffs

at about 1,000 feet. I spent most of this brief time taking movies, but had the chance to see the outer tower and the whole of the north side. The top of the outer tower slopes to the north, and is entirely covered with nesting fulmars. The colony extends more than one mile along the north side of the cape, some way west of our look-out place of the 16th and on to the first mountain. (This is rather greater than the extent of the colony on the south face.)

Farther north we saw a bear in the water, and flew over the unoccupied settlement of Kivitoo, where the buildings appeared to be in good repair. We landed among big ice floes at Clyde at 12.25.

Another account of the Cape Searle fulmars is to be found in my paper on the birds of the Baird expedition (Wynne-Edwards, 1952). It is in great measure complementary to this article, and comparatively little has been repeated in both places.

For the loan of the blocks of the coloured illustration my thanks are specially due to Mr. James Fisher of London, and to the Editors of the *Geographical Magazine*, in the August 1951 number of which journal the picture originally appeared.

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GRAVITY MEASUREMENTS ON THE BARNES ICECAP, BAFFIN ISLAND*

C. A. Littlewood

DURING the summer of 1950 I was sent north by the Dominion Observatory to make gravity observations as a member of the Arctic Institute's Baffin Island Expedition.[1] The main party was flown to Clyde, in east Baffin Island, in May 1950 by the R.C.A.F., and was later taken to the Barnes Icecap, 100 miles inland, by the expedition's Norseman aircraft. Return transportation was provided by the Department of Transport's vessel, the *C. D. Howe*, which also made stops at Pond Inlet and Arctic Bay, where regional gravity stations were established.

The gravity work on the expedition aimed at making a survey of the southeastern lobe of the Barnes Icecap, which is roughly 20 miles square, and at establishing as many regional gravity stations as possible. The objects of the survey were to attempt to determine the thickness of the ice and to outline the topographical features of the underlying rock surface.

Figure 1, which has been prepared from a preliminary base map drawn for the 8 miles to 1 inch map, shows the seven traverses, totalling 45 miles in length, along which gravity has been measured. The starting point of the survey was from Camp A, which lies approximately in the centre of the southeastern lobe of the ice cap. Three main gravity traverses AB, AC, and AD, each approximately 10 miles in length, were made from this point to the edge of the ice cap. Three shorter traverses EF, GH, and IJ, near the tip of the lobe, and another, KL, near its northern limit, were made to see if they would show evidence of subglacial valleys.

Field Methods

An engineer's transit and rod were used to locate the gravity stations and to measure their relative elevation. The stations are about 3,200 feet apart on the longer traverses and about 600 feet apart on the shorter ones. Rod readings could be estimated to one-tenth of a foot so that accumulated error on each of the traverses is not likely to exceed one foot. The absolute elevation for each station may be in error as much as ten per cent, since all elevations are relative to the elevation of Camp A, which was determined from a comparison of a number of aircraft altimeter readings taken at that point and at sea level. However, error in the absolute elevation in no way affects the computed ice thickness as only differences in elevation are used in the reduction.

The gravity measurements were made with a Worden gravimeter No. 44, which is light and sturdy; and therefore particularly well suited for a survey of this kind in which the long traverses had to be covered on foot. It is a

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[1]Led by Mr. P. D. Baird and supported by the Institute with funds provided through the U.S. Government. For general accounts of the expedition see *Arctic*, Vol. 3 (1950) pp. 131–49, and *Can. Geogr. J.* Vol. 42 (1951) pp. 212–23.

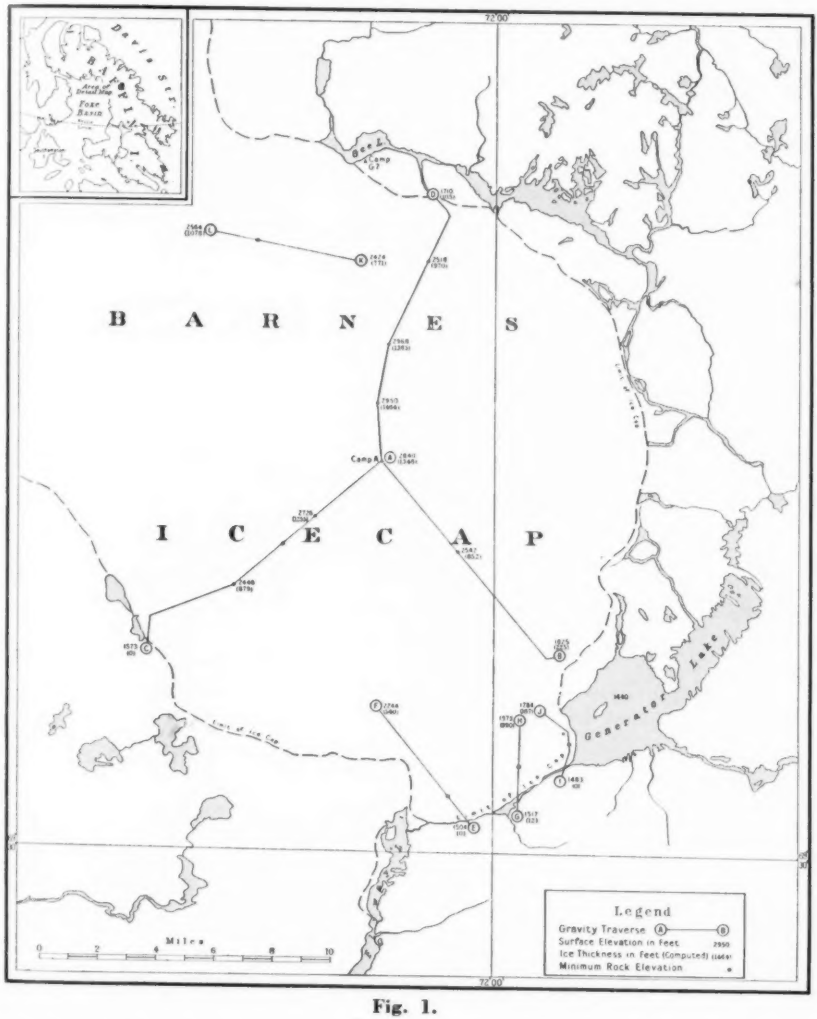


Fig. 1.

standard exploration instrument capable of measuring with precision small variations in gravity. This instrument was equipped with a high range reset mechanism which was controlled by a large dial calibrated in gravity units and could be used effectively for making long range gravity ties with no danger of the instrument going off-scale.

The constants of the instrument, as determined by tilt-table calibration and supplied by the manufacturer, are:

Large dial, 5.60 milligals per division.

Small dial, 0.10214 milligal per division.

A rough check on this calibration was made by reoccupying gravity stations established with pendulum apparatus at Goose Bay and at Frobisher Bay.[1] Comparison of the pendulum and gravimeter values is as follows:

	Pendulum	*Gravimeter*	*Difference*
Ottawa	980.622	980.6220	
Goose Bay	981.312	981.3164	+4.2 mg.
Frobisher Bay	982.167	982.1647	—2.3 mg.

The differences do not exceed the possible error of the pendulum determinations and since the measurements involve a large change in gravity, the calibration supplied by the manufacturer was accepted.

Drift of the instrument was determined on the basis of periodic repeat measurements at Camp A, whenever possible. However, because the long traverses required an absence from base for several days, an accurate drift curve for each day's operation could not be constructed. It was therefore necessary to adopt a mean drift for the instrument while in use, derived from the total drift and the overnight drift. Probably due to shock during transit over the more difficult traverses on the ice cap, a considerable amount of irregularity was noticed in the drift rate. This limited the relative accuracy of the adopted values of gravity for the stations to about 0.5 mg.

Reduction of observations and the accuracy of the method

The gravimeter method of determining the thickness of glacial ice was first used by Jean Martin[2] on the French Expedition to Greenland in 1948. It is based upon the assumption that the difference in the gravity anomaly for a station on the ice cap from the anomaly for some reference station situated at the outer limit of the ice, is due to a difference in the height of the rock floor above or below the level of the reference station. For if g_a is the observed value of gravity at the reference station, and g_b the observed value of gravity for a station on the ice cap, then

$$g_b - g_a = \Delta g = \Delta\gamma - K\Delta H + 2\pi G\ (\sigma_1 h_1 + \sigma_2 h_2)$$

where

$\Delta\gamma$ is the latitude correction based upon the International Gravity Formula. The correction is negative if the station is north of the reference point and positive if it is to the south.

σ_1=density of glacial ice (0.91 gm./cc.).

σ_2=density of rock (2.67 gm. cc.).

h_1=thickness of glacial ice.

h_2=height of the rock surface above or below the reference elevation.

$\Delta h = h_1 + h_2$=difference between the elevation of the field station and the elevation of the reference station where there is no ice or where the ice thickness can be measured by other methods.

K=free air correction factor= -0.09406 milligals per foot.

solving for h_2 gives

$$h_2 = \frac{\Delta g - \Delta\gamma + (K - 2\pi G\sigma_1)\Delta H}{2\pi G\ (\sigma_2 - \sigma_1)}$$

$$\text{or } h_2 = \frac{\text{Bouguer anomaly (using the density of ice)}}{2\pi G\ (\sigma_2 - \sigma_1)}$$

[1]Beer, M. "Measurements of gravity in the Canadian Arctic and Greenland". *Can. J. Res.* Vol. 28 (1950) pp. 535-41.

[2]Martin, J. "Gravimétrie" in 'Rapport préliminaire de la campagne préparatoire au Grœnland'. 5 Série Scientifique (1948) pp. 28-41.

If the Bouguer anomaly is positive, h_2 is positive and the rock elevation is greater than the reference elevation. The opposite is true if the anomaly is negative.

Before applying this formula to the results $\triangle g$ must be corrected for the departure of the topography near the gravity station from an infinite plane. With the available information this terrain correction could be assessed using standard methods to within 0.2 milligal. $\triangle g$ must also be corrected for regional changes in gravity due to both deep-seated effects and density changes in the near surface rock formations. There is no precise means of making this correction since the only information concerning the regional change is contained in the Bouguer anomalies for those stations established beyond the limit of the ice or for those for which the ice thickness is known by other methods. It is therefore necessary to assume that the gradient of gravity due to these causes is linear between the control points of the traverses. While such an assumption may produce little error in the shorter traverses, there may be large errors introduced in the longer ones. It has been found that changes in the density of surface rocks in other areas of the Precambrian Shield can produce gradients as much as six milligals per mile.

Assuming that the regional corrections are precise and that the densities used in the reductions are correct, 2.67 for rock and 0.91 for ice, an error of one milligal in the gravity anomaly produces an error of about 45 feet in the computed thickness of glacial ice. An error of one foot in the relative elevation of a gravity station produces an error of about 4 feet in the computed ice thickness. The combined errors in the determination of position, relative elevation, relative gravity, and terrain correction will not be greater than 0.8 milligal and should be usually smaller than this amount. The error in the computed ice thickness due to these causes should be within $\pm$ 35 feet.

Apart from these sources of error the gravity method at its best can but indicate the order of magnitude of ice thicknesses. This follows directly from the theory in which it is assumed for mathematical convenience that the rock surface beneath the ice approximates an infinite level sheet. Therefore the precision of the gravity method depends on how closely the rock surface does approach this condition. The precision also decreases with increasing ice thickness. For example, an increase in the gravity anomaly of 1 milligal is interpreted as indicating a general rise in the rock floor by about 45 feet. However, if the thickness of ice was approximately 1,200 feet, a rocky ridge 400 feet wide and rising about 400 feet directly below the gravity station would produce only the same gravity anomaly. From this it is apparent that gravity measurements alone cannot indicate such variations in the rock surface below ice thicknesses of this order.

Results and conclusions

Table 1 gives the principal facts for all regional stations including those established en route to and from Baffin Island. Stations designated by letters are end points of gravity traverses made over the ice cap as shown in Fig. 1. The Bouguer correction for all stations whether situated on the ice cap or not has been made assuming a density of 2.67 gm. per cc. The Bouguer

Station No.	Station Name	Longitude °	Longitude ′	Latitude °	Latitude ′	Elevation, ft.	Theoretical gravity, γo	Corrections: Elevation	Corrections: Bouguer	Computed gravity: Free Air	Computed gravity: Bouguer	Observed gravity	Gravity anomalies: Free Air	Gravity anomalies: Bouguer
1	Goose Bay	60	25.6	53	19.2	131	981.3704	−0.012	−0.008	981.358	981.362	981.3164	−0.042	−0.046
2	Fort Chimo	68	24.5	58	06.0	105	.7723	− .010	− .006	.762	.766	.7276	− .034	− .038
3	Frobisher Bay	68	33.3	63	44.8	67	982.2056	− .006	− .004	982.200	982.202	982.1647	− .035	− .037
4*	Pond Inlet	77	59.6	72	41.7	10	.7618	− .001	− .001	.761	.761	.7251	− .036	− .036
5*	Arctic Bay	85	10.0	73	02.0	12	.7790	− .001	− .001	.778	.778	.7467	− .031	− .031
6*	Clyde	68	33.8	70	27.3	10	.6401	− .001	− .001	.639	.639	.6390	.000	.000
7		71	07.3	70	50.2	0	.6634	.000	.000	.663	.663	.6243	− .039	− .039
8		70	39.1	70	25.3	0	.6382	.000	.000	.638	.638	.5898	− .048	− .048
9		70	23.5	69	49.7	0	.6024	.000	.000	.602	.602	.5713	− .031	− .031
10		70	07.1	69	59.2	0	.6131	.000	.000	.613	.613	.5730	− .040	− .040
11		69	01.7	69	58.2	0	.6121	.000	.000	.612	.612	.5830	− .029	− .029
12	Camp G 7	72	11.1	69	50.6	1542	.6047	− .145	− .093	.460	.512	.4873	+ .027	− .025
A	Camp A	72	09.6	69	41.6	2840	.5959	− .267	− .170	.329	.426	.3674	+ .038	− .059
B		71	54.8	69	35.8	1825	.5902	− .172	− .110	.418	.480	.4458	+ .028	− .034
C		72	29.0	69	35.9	1573	.5903	− .148	− .094	.442	.496	.4647	+ .023	− .031
D		72	05.1	69	49.4	1710	.6036	− .161	− .103	.443	.501	.4742	+ .031	− .027
E		72	01.9	69	30.9	1504	.5854	− .142	− .090	.443	.495	.4704	+ .027	− .025
F		72	09.6	69	34.3	2244	.5887	− .211	− .135	.378	.454	.4129	+ .035	− .041
G		71	57.9	69	31.3	1517	.5858	− .143	− .091	.443	.495	.4712	+ .028	− .024
H		71	57.8	69	33.8	1973	.5882	− .186	− .118	.402	.470	.4337	+ .032	− .036
I		71	54.2	69	32.3	1483	.5867	− .140	− .089	.447	.498	.4747	+ .028	− .023
J		71	55.6	69	34.2	1784	.5886	− .168	− .107	.421	.482	.4504	+ .029	− .032
K		72	11.9	69	47.6	2424	.6018	− .228	− .145	.374	.457	.4140	+ .040	− .043
L		72	23.9	69	48.4	2564	.6026	− .241	− .154	.362	.449	.3994	+ .037	− .050

* These stations are located at astronomical monuments of the G.S.C.

Table 1. Principal facts for gravity stations.

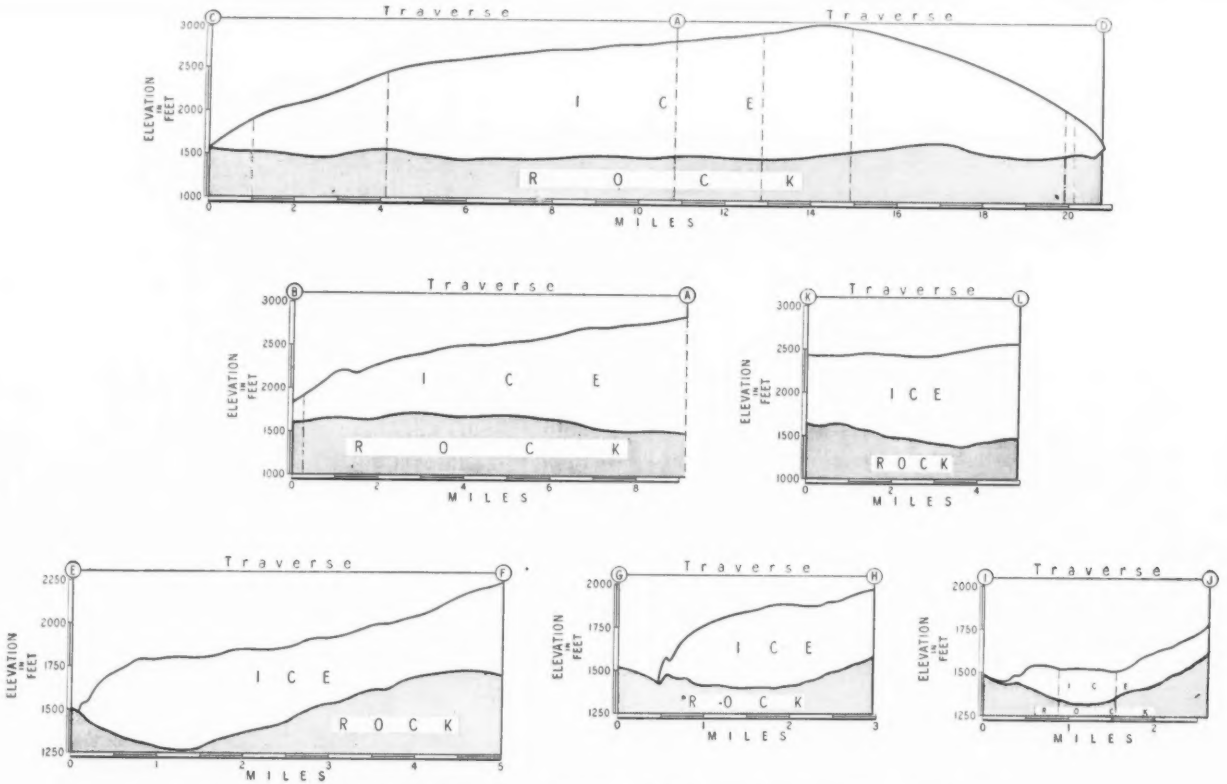


Fig. 2. Cross sections of the gravity traverses. The dotted lines indicate turning points.

anomalies for those stations beyond the limit of the ice were used to determine the regional correction.

The measured surface elevations and the computed rock elevations and ice thicknesses for the traverses are shown diagrammatically in Fig. 2. Table 2 gives these measurements and the differences in gravity corrected for terrain for traverse AB, selected as a typical traverse.[1]

Station	*Distance from reference station in miles*	*Observed gravity difference in milligals*	*Surface elevation in feet*	*Rock elevation in feet*	*Ice thickness in feet*
B–28	0.00	–18.52	1825	1600	225
27	0.59	–34.09	2026	1641	385
26	0.89	–43.83	2151	1653	498
25	1.48	–46.89	2192	1644	548
24	2.24	–55.37	2318	1684	634
23	2.93	–60.38	2391	1718	673
22	3.52	–66.82	2469	1696	772
21	4.38	–69.25	2506	1690	815
20	5.11	–71.57	2542	1690	852
19	5.86	–75.61	2591	1658	932
18	6.44	–81.57	2658	1619	1039
17	7.15	–87.01	2711	1540	1170
16	7.89	–90.30	2751	1516	1235
15	8.52	–92.97	2791	1517	1274
A–12	9.13	–97.00	2840	1494	1346

Table 2. Computed rock elevations and ice thicknesses along Traverse AB.

Considering first the longer traverses CAD and AB, the greatest ice thickness indicated by the results is 1,533 feet. This occurs near mile 14 on traverse CAD. For the reasons already mentioned, where ice of this thickness is found, abrupt changes in the computed rock elevations would not be expected. The greatest slope is along AD where the rock elevation changes about 60 feet in a distance of three-quarters of a mile. The results show that the floor of the ice cap near the middle of the lobe is on the average about 100 feet lower than it is near the margin.

Somewhat similar results are obtained for the shorter traverse KL. The indicated ice thickness averages roughly 1,000 feet, and there is a small depression of the rock floor reaching a minimum about mile 3.7.

The shorter traverses EF, GH, and IJ were surveyed to see if the results would confirm the existence of the subglacial valley which was suggested by the topography. The sections in Fig. 2 show that at about mile 1.3 along each traverse the rock elevations are 100 to 200 feet lower than the respective reference stations. The locations of the points of minimum rock elevation are given in Fig. 1 and their relative positions do suggest the course of a valley beneath the ice extending from Generator Lake to the northern end of Flyway Lake. Because of the greater density of gravity stations along these traverses and because the indicated ice thickness seldom exceeds 500 feet and is usually much less than this amount, there is a good possibility that the results are comparatively accurate. The indicated rise in the rock floor near mile 0.5 on both GH and IJ is most likely due to morainic material in the ice.

I wish to thank Mr. Hans Röthlisberger and Mr. Franz Elmiger of Switzerland and Mr. J. D. C. Waller of Montreal for their assistance in carrying out the survey. I am also indebted to various members of the staff of the Dominion Observatory for their help in the preparation of this report.

[1]These figures are available for all traverses at the Montreal Office of the Institute.

REVIEWS

MINERAL INDUSTRY OF DISTRICT OF MACKENZIE, NORTHWEST TERRITORIES

By C. S. Lord. *Ottawa: Geological Survey of Canada Memoir 261, 1951. 9½ x 6½ inches; ix+336 pages; plate, diagrams, and folding maps. $1.25.*

The greatest concentration of the mineral industry in the Northwest Territories is in the Yellowknife area where, following the discovery of gold on the east side of Yellowknife Bay on the north shore of Great Slave Lake, the settlement of Yellowknife was founded in 1935. It was that year that gold was first found on the west side of the bay, and which led to the development of the Con, Negus, and Rycon mines. In 1944 important gold deposits were found on the property of Giant Yellowknife Gold Mines and, during the following two years the rich ore disclosures on the Giant claims sparked one of the most exciting gold rushes in the history of Canadian mining. During that period it is estimated that more than three hundred companies were formed on properties north and east of Yellowknife and hundreds of discoveries were made in a vast area of geologically favourable formations.

As a result of these activities, however, only one mine other than Giant Yellowknife was developed to successful production before rising costs due to post-war inflation curbed the flow of funds necessary for mine development. On the other hand, more than a dozen discoveries were developed to various stages sufficient to indicate good prospects for commercial production at some future time when adequate funds were available. In 1948, following the relaxation of restrictions on prospecting for radioactive ores, there followed a new surge of exploration directed towards geological formations of younger age than those in which the gold deposits occur and, since the outbreak of fighting in Korea, prospecting emphasis has been transferred to the search for base metal deposits.

In Memoir 261 Dr. Lord has recorded the sober facts resulting from these past activities, and has presented the geological background on which to assess them. Ten years have elapsed since the publication of the predecessor volume, also by Dr. Lord, entitled 'Mineral Industry of Northwest Territories' (Geological Survey Memoir 230). This earlier volume, a slim prototype of its present successor, dealt with mining activities up to 1939. The present publication, in effect a second edition, but restricted to Mackenzie District in which almost all important mining activities of the Northwest Territories are located, covers developments up to 1947. The relatively considerable lapse of time between then and the publication date of 1951 is unfortunate as many important mineral developments during the past three to four years have not been recorded. Thus the volume is not up-to-date with respect to the development of high-grade zinc ores at Indian Mountain Lake, silver-bearing lead ores in the vicinity of O'Connor Lake, and uranium ores both in the east arm of Great Slave Lake and at Hottah Lake.

A total of 139 mineral properties is described in Memoir 261 and on many of these properties are several veins or mineral deposits. Dr. Lord has personally examined most of them, many several times, and he has visited all the important developments disclosed up to 1947. Probably no publication of the Geological Survey of Canada contains more factual data on the dimensions and grades of ore shoots and mineral deposits. Such data together with the geological background make an outstanding contribution, involving not only an accurate description, but making possible an evaluation of the various prospects. This volume is indispensable to the prospector, mining geologist, the engineer, and the investor, who are interested in the Northwest Territories.

J. D. Bateman

CLIMATE IN EVERYDAY LIFE

By C. E. P. Brooks. *New York: Philosophical Library, 1951. 8½ x 5½ inches; 314 pages; sketch-maps and diagrams. $4.75.*

The author of this book is best known for his outstanding work on the theory of climatic change. For many years he was head of the Climatological Division of the British Meteorological Service, and it was this experience that prompted his new book. It deals with the economic, physiological, and psychological effects of climate on the everyday life of western man. In 1946 Dr. Brooks gave a paper on the deterioration of materials under exposure to climate at the Royal Meteorological Society in London. He was overwhelmed by requests for more information, and so decided to condense his encyclopaedic knowledge of applied climatology into book form.

He begins by a discussion of "living with the climate", which is a broad and generalized account of world climates and their effect, mostly inimical, on man and his capital equipment. There is a long, though hardly exhaustive, study of the siting and design of houses and factories in relation to climate. The classification of climates used is of an odd kind, being in part typically geographical (e.g., Mediterranean climates) and in part based on hazard ("Deterioration" climates, Typhoon and Hurricane climates). The treatment of the Arctic climates is inadequate: it is quite clear that Dr. Brooks is writing mainly about the tundra, yet on Fig. 1 he takes in all of Alaska, including the entire Pacific coast, the forested Labrador plateau and many forested areas in Siberia within this division. All these areas have climatic extremes and norms quite unlike those of the true Arctic. The confusion arises from the adoption of the poleward limit of agriculture as the boundary.

Dr. Brooks then proceeds to an interesting account of climate as an enemy, dealing with pollution, the deterioration of materials, and climatic accidents, the lattermost comprising the effect of floods, gales, storms, and other so-called acts of God. He then gives a review of climatic control, meaning by this suggestive term the efforts made by man to alter his environment. Heating, lighting, and air-conditioning come in for most attention, but rain-making and hail-control are also discussed.

As a guide to British civil servants and business men this book will be quite useful. For a North American public, and especially one concerned with the cold environments, it is less to the point. In Dr. Brooks' own words (on page 18), ". . . we eliminate those parts of the world which have little interest for our purposes: (i) Polar regions and tundras . . ."! F. K. Hare

THE SITKA DISTRICT

By Ralph Browne. *Juneau, Alaska: Alaska Development Board, 1950. 10½ x 8½ inches; 81 pages; tables; mimeo.*

THE CORDOVA DISTRICT

By Ralph Browne. *Juneau, Alaska: Alaska Development Board, 1951. 10½ x 8½ inches; 81 pages; tables; mimeo.*

In 1945 the Alaskan Legislature created the Alaska Development Board, as a part of the Governor's staff, to encourage interest and development in the Territory. Under the direction of George Sundborg and his assistant Ralph Browne the Board has published several pamphlets and reports, produced the excellent Machetanz film, and encouraged new interest in Alaska both Inside and Outside. The Sitka and Cordova reports are the beginning of a series of "comprehensive surveys of business and industrial opportunities" in small parts of the Territory. The series was begun in these two cities because of the cooperation offered by their local Chambers' of Commerce.

The two reports cover the same ground, with chapters on general information (e.g. location, climate), the city (e.g. housing, health), mining, forestry, agriculture, fisheries, water, transportation, and recreation. The style of writing is generally direct and simple and it is refreshing to note the constant references to relationships of the Territory and other parts of the world. However, by far the strongest points of the

reports are the comments on information required and on recommendations for future investigations. Social scientists can profit greatly by noting the topics and problems for research which are highlighted.

As promotional documents the reports serve a useful purpose. This is to interest potential businessmen, investors, and settlers in Alaskan enterprises. It is clear that the reports are not designed to be scientific documents. Sources of data generally are not indicated, few basic references (other than U.S. Geological Survey Bulletins) are listed, and no maps are included. There is great variation in degree of detail in the descriptions, ranging from inadequate comments on climate to detailed observations on mountain climbing and individual power and mining sites. Somewhat disturbing are the inclusions of unnecessary (for the declared objective of each report) sections on such things as the past restrictions of government on coal and oil leasing (Cordova report, p. 67) and the repeal of section 27 of the Jones Act (Sitka report, p. 58). The intended audience appears to vary between potential businessmen, Cordovan and Sitkan residents, United States citizens, and U.S. congressmen—a confusing, if not too diverse, range. It is surprising, too, that analyses of items like costs of living, labour, and materials are omitted—topics of paramount interest to businessmen and analysts alike.

The optimistic attitude of the reports is basic to promotional publications. Yet, the constant optimism, in spite of any noted difficulty (and those not noted), raises the question of possible danger from overselling. KIRK H. STONE

AN INTRODUCTION TO THE GEOGRAPHY OF THE CANADIAN ARCTIC

Ottawa: Geographical Branch, Dept. Mines and Technical Surveys, 1951. Canadian Geography Information Series No. 2. 9 x 6 inches; xiii + 118 pages; sketch-maps, folding maps, and illustrations. 50 cents.

It is a useful step forward to have a single short publication on the geography of the Canadian Arctic, replacing the now considerably out-of-date booklets on specific divisions. These earlier ones however, did have some literary merit. The various chapters of the present publication give a broad picture of conditions in the region, but the treatment of subjects is rather uneven. The topographical section is full and good; the chapter on settlement is peculiar in singling out only seven settlements for detailed treatment, one of which is now abandoned.

Perhaps in the chapter on climate not sufficient attention is paid to the varying pressure pattern which so influences the vital arctic factor of wind, and although the data are still very recent, I feel that some more information from the far northern weather stations could well have been included, e.g. the very low mean winter temperatures and precipitation of Eureka which establish several Canadian "records".

In the section on wildlife, the importance of the two seals which can be hunted through the ice in the winter, as opposed to the remainder of the marine mammals which appear to migrate to open water, should have been brought out. One of the most surprising statements in the book is that "[walrus] hide is often used for bed robes" (p. 42). I can imagine nothing more uncomfortable.

With regard to the history of exploration, it is extremely difficult to give any brief account of the work accomplished since the First World War, but in view of the considerable detail given for the earlier history, I think some of the trends of modern exploration and the outstanding names should have been given.

The booklet is well filled with maps, but since these were specially drawn in 1951, they could perhaps have been a little freer from errors, e.g. the location of ice caps on the geology map opposite page 2, an error in Parry's 1824 expedition, and considerable confusion between Greely, Nares, and Peary in the maps on exploration. Reproduced in all the maps is one major error: Stefansson Island is not a severed portion of the northeast

peninsula of Victoria Island as shown here, but a new island farther to the north.

The absence of any statistical information is surprising. From this point of view alone, the publication compares very unfavourably with recent Danish Government material on Greenland.

'An introduction to the geography of the Canadian Arctic' seems adequate for high school students, but not for more serious readers. One looks forward to seeing it revised with more equal treatment of the different subjects, and with the inclusion of up-to-date statistical material.

P. D. BAIRD

INSTITUTE NEWS

Looking south from Teshierpi Mountain, from a painting by A. Y. Jackson.

Presentation of painting to Dr. and Mrs. A. L. Washburn

On 13 May 1952 the Arctic Institute presented Dr. and Mrs. A. L. Washburn with a painting by A. Y. Jackson, C.M.G. The following inscription was engraved on a small plaque: "Presented to Linc and Tahoe Washburn by the Arctic Institute of North America in appreciation of their whole-hearted work in the interests of the Institute, 1945-51".

A. Y. Jackson painted this picture, which is entitled "Looking south from Teshierpi Mountain", from a sketch made in August 1950. At this time he was on a painting trip sponsored by the Department of Resources and Development and the Eldorado Mining Company. Teshierpi Mountain is in the Barren Grounds, just south of Dismal Lakes, midway between Hornby Bay of Great Bear Lake and Coronation Gulf.

New quarters of the New York Office

Some time ago the Director of the American Geographical Society advised me that owing to the expanding activities of the Society he was reluctantly forced to ask the Institute to relinquish the space that the New York Office had occupied in the Society's building since 1947. Every effort was made to secure accommodation which would answer most effectively the administrative needs of the New York Office and at the same time provide an association with an organization with parallel interests to those of the Institute.

By great good fortune this has been met through the hospitality of the New York Academy of Sciences. The address of the new quarters in the Academy's building is c/o New York Academy of Sciences, 2 East 63rd Street, New York 21, N.Y.

WALTER A. WOOD
Director, New York Office

Visit of N. O. Christensen

Kontorchef N. O. Christensen (previously acting Landsfoged for North Greenland) visited the Montreal Office of the Institute during the last week in May. He had flown directly from Greenland to Canada and will be travelling on the *C. D. Howe* this summer as the guest of the Northwest Territories Administration. He will thus have an opportunity to study administrative practices in the Eastern Canadian Arctic, and in return the Canadian authorities will be able to learn from him at first hand many of the administrative and native welfare practices in Greenland, where there has been so much change in recent years. His visit was made possible by a United Nations Fellowship.

NORTHERN NEWS

Discovery of Russian hydrographic bottles and barges off west Greenland

Dr. Trevor Lloyd, who was in Greenland during the summer of 1951, has sent the following information on Russian hydrographic bottles and barges found off the west coast of Greenland.

On 16 June 1951 a Greenland fisherman from Narssalik, between Frederikshaab and Ivigtut, found a Russian hydrographic bottle floating in the sea. He broke the glass and turned the paper over to the Administration. The paper was a typical hydrographic record, and had printed instructions in Russian, English, and Norwegian to return the paper to the Arctic Institute of the U.S.S.R. in Leningrad, with a statement of the date and place of finding. There was no record of where the bottle had been released, but the paper bore a statement that it was used to study the movement of ice and so was presumably of arctic origin and had drifted down the east coast of Greenland and had then been caught in the West Greenland Current.

In *Grønlandsposten* for 16 January 1952 there is an account of the finding of another Russian bottle. On 14 August 1951 the fisherman Ezekias Møller found some driftwood a little east of Napassok, to the north of Godthaab, which he took home with him. In January of 1952, when about to chop the wood up, he found a hole in it stopped with a plug, and inside a glass container. The paper inside the container was similar to that found in June 1951. The account in *Grønlandsposten* adds the information that a similar container was found at Prøven in 1937 and that the Arctic Institute of the U.S.S.R. reported that it had been released in September 1932. Therefore it is probable that the two bottles found in 1951 were put into the sea around 1946.

A more interesting find is that of two wooden barges floating in Davis Strait. These were marked with Russian names and dates carved in the gunwales, and were brought ashore at Islandsdalen, a "suburb" of Godthaab, about 1949. Unfortunately the barges were cut up and

used for fuel. Dr. Lloyd could not find any pieces on the beach in July 1951, nor any record of the names or dates carved on the barges, though he heard 1942 mentioned as probably the correct date. This information about the barges came from the Administration and was widely known to the local fishermen, so it is undoubtedly true. The barges were presumably river barges used on the Siberian rivers; these are generally very large and heavy in construction. In the spring the ice on these rivers breaks up with enormous force and the two barges were probably carried out at this time of year. Seven years would seem a reasonable period for the drift by way of the east Greenland coast.

Dr. Lloyd adds the comment that it is not unusual to find large amounts of driftwood of Siberian origin on the southeast coast of Greenland. When visiting the Rev. Otto Rosing at Egedesminde in 1951, he was told that "much of my furniture came from Russia"—a reference to Otto Rosing's many years at Angmagssalik where the best lumber comes from the sea. Firewood probably of Siberian origin is used in outposts a few miles south of Godthaab in west Greenland.

The Seismic Observatory at Resolute Bay[1]

In 1948 a survey made at Resolute Bay by the Dominion Observatory gave a favourable report on the feasibility of establishing and operating a seismological observatory in the severe arctic climate. The most important prerequisite, bedrock, for receiving seismic radiation, was discovered near a small river one thousand feet south of the station. Plans were accordingly laid to bring the station into operation.

A rigorous field test of equipment was carried out on the Experimental Farm in Ottawa during the winter of 1949-50; in July of 1950 P. C. Bremner and R. E. Andrews, the latter a student at the University of Toronto, flew north to establish the station. The detecting seismometers were placed on bedrock and enclosed in a small building which was then banked with gravel to provide temperature control and reduce the effects of strong winds. The building can only be entered through a trap-door level with the ground, and two one-hundred watt light bulbs provide sufficient heat to keep the vault at a comfortable working temperature during the coldest season of the year. Several cables lead from the building housing the detecting seismometers to the recorder building located in the weather station. The recording apparatus is set up on steel tables which are anchored in the permanently frozen ground and housed in a specially designed double-walled prefabricated building made by the Tower Construction Company. Within two months after the seismic crew landed at Resolute important data on distant earthquakes were being radioed to the south. P. C. Bremner remained in charge of the Observatory during 1951 but R. E. Andrews recently returned to Resolute to operate the station during 1952.

While there has been little indication that the Eastern Arctic Islands are seismic, few days pass that an earthquake is not recorded at the Resolute Bay Observatory. Earth tremors from Alaska, the Aleutian Islands, and occasionally from northern Siberia will often shake the seismometers so violently that only the first shock wave is well recorded. The remainder of the record may be obscured as the result of the intense ground movement too small for detection by human senses but violent enough to destroy the usefulness of the seismometer. The arrival time of the first shock wave is of great importance and this information is radioed at once to Ottawa, then to Washington where data are collected from all over the world. The United States Coast and Geodetic Survey uses this information to determine the location, and depth in the earth, of the earthquake and sends its results to stations studying these phenomena.

Today, with the experimental stage of the installation almost over, Resolute is

[1]Reprinted from the *Arctic Circular*, Vol. 5, No. 1 (1952) pp. 9-10. Published by permission of the Director-General of Scientific Services, Department of Mines and Technical Surveys, Ottawa.

ranked as one of the leading stations in the world. It is located in such a position that seismologists may study, in conjunction with other observatories, the geological structure beneath the Arctic Ocean, the Bering Sea, and North America. It may prove valuable in solving the mystery of microseisms, a periodic ground disturbance associated with the passage of cold fronts and more spectacularly with the movement of storms at sea. Much work is needed to improve the instrumentation to carry out this research but the most difficult stage has been completed. There are few stations which today have the great opportunities offered to seismologists in charge of the Resolute Bay Observatory.

P. C. BREMNER

CORRESPONDENCE

To the Editor:

I read with interest Dr. Jacques Rousseau's review of 'Terre Stérile' by Jean Michéa in the September issue of *Arctic*, which reached me on Wednesday last. Dr. Rousseau states that Michéa mentions that syllabic Eskimo was invented by the Moravian missionaries of the Labrador Coast, who taught it to the Naskapi Indians and to the local Eskimo. Dr. Rousseau is correct in suggesting that Michéa is incorrect in this statement. In the first place the Moravian missionaries never worked among the Naskapi Indians on this Coast and secondly the Mission has always used Roman characters in its Eskimo publications both here and in Greenland.

Jens Haven, the first missionary of our Church here in Nain, who came here in the year 1771 had formerly been a missionary in Greenland and I have in my possession at Nain a New Testament in the language of the Greenland Eskimo translated by Paul Egede and printed in 1766. Also I have a handwritten Catechismusiorvik—that is an Eskimo Catechism—written in the year 1769. It is inconceivable that Moravians having access to the Scriptures in the Eskimo language should go to the trouble to invent a new form of writing. The Naskapi Indians of this Coast use syllabic but I have no knowledge of when they first began to use it, but would think that it was probably at some fairly late date.

(REV.) F. W. PEACOCK,
Superintendent of Moravian Missions in Labrador,
Nain,
Labrador
22 February 1952

GEOGRAPHICAL NAMES IN THE CANADIAN NORTH

The Canadian Board on Geographical Names has recently adopted the following names and name changes for official use in the Northwest Territories. For convenience of reference the names are listed by the maps on which they may be found. The latitude and longitude given are approximate only and refer to the first letter of the name except where a precise location is given for a place or a spot height for a mountain.

Amundsen Gulf, 97 N.W. and 97 N.E. (8 miles to 1 inch)

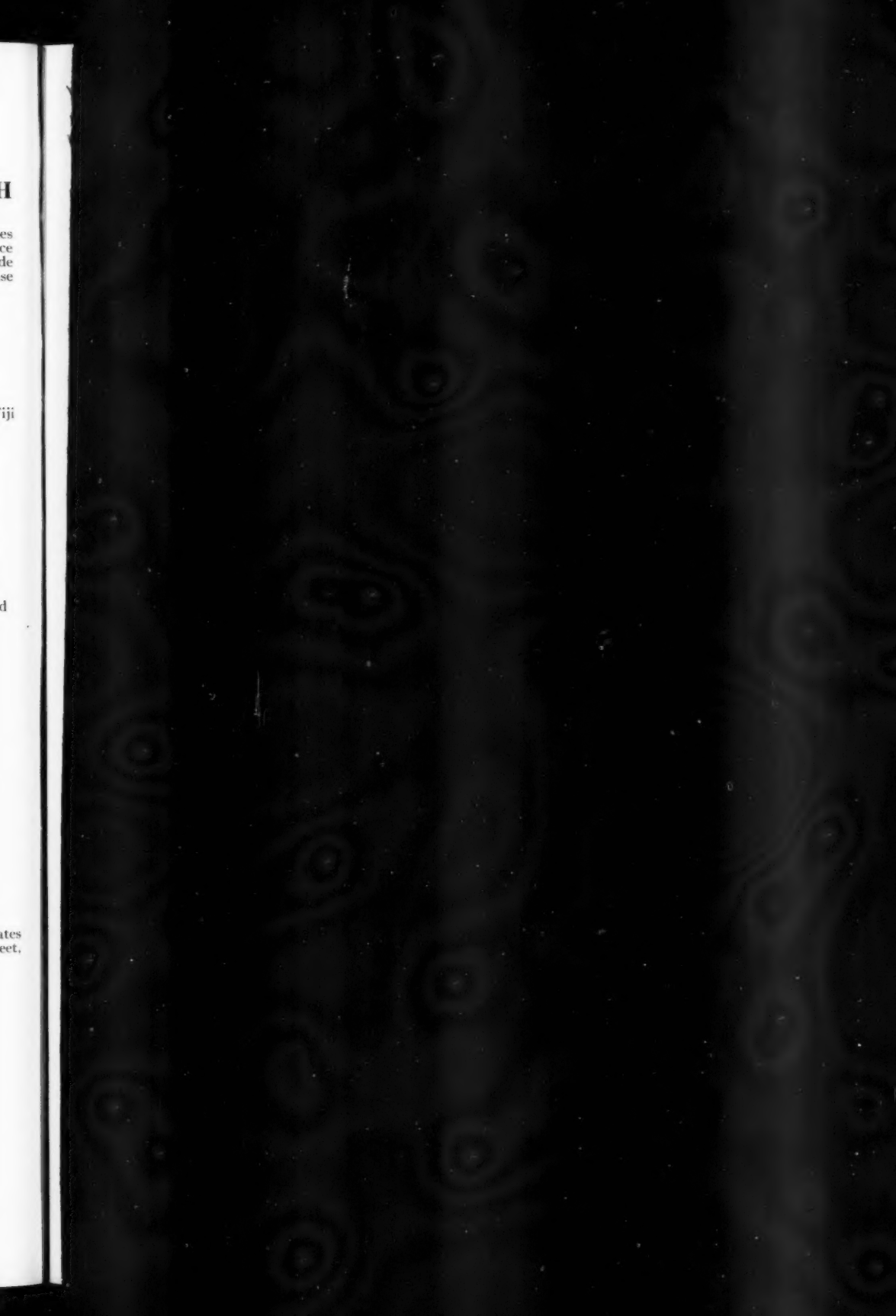
(*Corrections adopted on 6 June 1952 to the list of 4 October 1951*)[1].

Balaena Bay	70°	01N.,	124°	58W.	not Bolina Bay
Booth Island	70	06	125	19	not Big Booth Island
Canoe Island	70	11	124	55	not Northeast Booth Island
Fiji Island	70	09	125	17	not Little Booth Island

(The name Booth Islands is retained for the group now designated Booth Island, Fiji Island, and Canoe Island).

Melville North, 47 S.W. and 47 N.E. (8 miles to 1 inch)

(*Adopted 2 August 1951*)

Alfred Island	69°	51N.,	85°	16W.	not High Island
Augarnar Point	69	43	81	06	not Augarnarsuk (point) nor Seal Point
Cape McLoughlin	68	45	85	48	not Cape Macloughlin nor Cape McLaughlin nor Cape M'Loughlin
Cape Sibbald	68	19	85	57	
Crown Prince Frederik Island	69	58	87	08	not Crownprince Frederik Island nor Crown Prince Frederick Island nor Hall Island
Deer Island	69	47	80	39	
Elder Island	69	51	82	38	not Prince Knud Island nor Elder (Prince Knud) Island
Fraser Bay	68	27	85	50	
Foster Bay	68	58	81	28	
Gifford Fiord	69	59	81	53	not Gifford River nor Gifford Inlet
Griffiths Bay	69	40	83	28	not Griffiths Creek
Ignertok Point	68	19	81	59	not Ignertoq (point)
Ikerasak River	68	34	82	20	
Kite Island	68	43	82	07	
Mackar Inlet	68	26	85	42	
Northeast Cape	69	41	82	32	not North East Cape
Prince Albert Hills	68	12	85	07	not Prince Albert Mountains nor Connaught Mountains
Skeoch Bay	69	32	80	19	not Skeogh Bay
Tangle Island	69	23	80	10	
Walrus Island	68	41	82	19	
(*Adopted 6 March 1952*)					
Sévigny Point	69	47	82	09	not Sevigny Point

1. The list of 4 October 1951 was published in *Arctic*, Vol. 5 (1952) p. 63. The coordinates given in the above list refer to the names on the 1951 edition of the 8 miles to 1 inch sheet, not the new names listed here.